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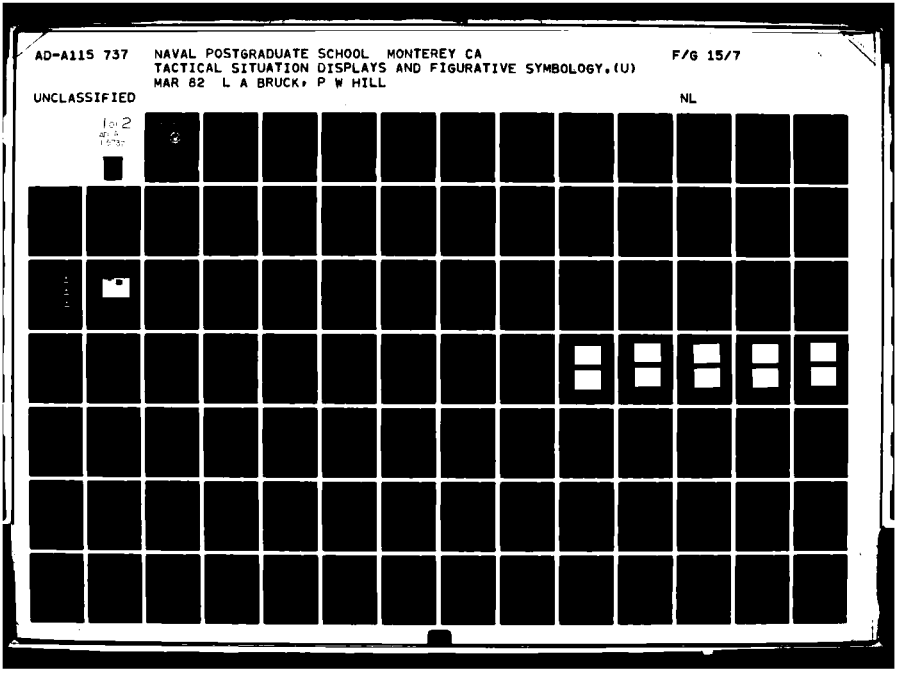

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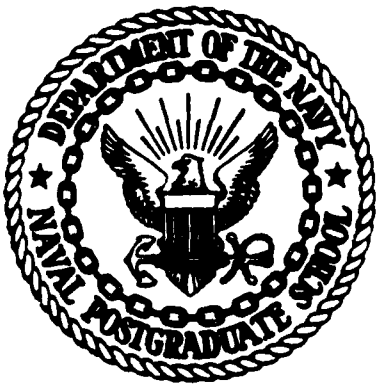

THESIS

TACTICAL SITUATION DISPLAYS
AND FIGURATIVE SYMBOLOGY

by

Lawrence Alan Bruck
Philip Wayne Hill

March 1982

Thesis Advisor: F.R. Richards

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): Tactical Situation Displays and Figurative Symbology	5. TYPE OF REPORT & PERIOD COVERED: Master's Thesis; March 1982
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Lawrence Alan Bruck Philip Wayne Hill	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Postgraduate School Monterey, California 93940	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Postgraduate School Monterey, California 93940	12. REPORT DATE: March 1982 13. NUMBER OF PAGES: 108
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Tactical Situation Displays
Color Displays
Figurative Symbols
Command and Control Symbology

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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Tactical Situation Displays and Figurative Symbology

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS TECHNOLOGY
(COMMAND, CONTROL AND COMMUNICATIONS)

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

This thesis investigates the utility of figurative symbology for tactical situation displays. The purpose was to determine if more descriptive symbology--figurative symbology or use of more lifelike images to represent targets--would enhance evaluation of a tactical situation display, i.e., enable the user to more rapidly assimilate and evaluate a tactical situation display. Basis for comparison was the Navy Tactical Display System (NTDS). Specifically, experiments used in our research included comparisons of monochromatic NTDS, color NTDS, and color figurative symbologies.

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ACKNOWLEDGEMENTS

We wish to gratefully acknowledge the guidance and encouragement of our thesis advisor Professor F. R. Richards, without whose assistance this thesis would not have been possible. We would also like to acknowledge the time and assistance given by our second reader, Professor G. K. Poock. Additionally, our thanks to the students of the Naval Postgraduate School who generously volunteered their time to be subjects for our research. Finally, our sincere thanks and appreciation to our wives, whose encouragement and moral support made this effort possible.

I. INTRODUCTION

A. BACKGROUND

The use of military symbols dates back at least to the days of Napoleon. Warfare has changed considerably since that era and so have the methods by which the battlefield environment is graphically portrayed. [Ref.1] The wars of yesteryear were very localized. Battlefields were often of a size that permitted a commander to view the entire battle area from a hilltop vantage point. Under these conditions, a commander could track all of his activity with a table-top situation display. The geographical area portrayed was small, and the number of symbols required to indicate activity was minimal. Rapid movement of units was a rare event, so frequent updating of the display was not a requirement. Now, with mechanized infantry, armor, missile and rocket installations, supersonic aircraft, airmobile units, multipurpose naval vessels, etc., the variety of symbols required has greatly proliferated. [Ref.2]

B. HISTORICAL PERSPECTIVE

"Military commanders throughout history have faced the problem of controlling their forces for decisive application of military power, with the objectives of achieving a desired physical action at a particular location at a determined time and of getting information back about the

outcome." [Ref.3] In the first documented times of early warfare, "battle commanders sought a high hill or other vantage point from which to view the battle's progress. They invented various means of providing the communications with which to command forces: mirrors, flags, harps, horns, drums, and even messengers." [Ref.4] Information feedback to the commander was through direct observation and commands could be issued or reissued in time to direct/redirect forces. "As the geographical scope of warfare and the mobility of forces increased, the ability to instrument the battle in such a way that a coherent picture of it could be transmitted to a remote commander, and the communications necessary to transmit a timely picture, failed to keep pace."[Ref.4] Land force commanders began to move flags about on charts or sand tables, using bits and pieces of intelligence information about enemy disposition and operational reports from friendly forces. Naval commanders used similar methods, as did Air Defense commanders to try to watch and control their forces. The commander with the most accurate and timely information and the best communications to support information flow should be successful in his pursuit. [Ref.4]

This process of generating, disseminating, and digesting information became an important part of the formula for success. With the growing appetite for information came radar. "The air defense commander was no longer dependent

upon ground observer or combat patrol reports for vital information on enemy aircraft position or velocity." [Ref.4] He could determine the location of friendly aircraft and could now see the air battle coherently and control his forces. Certainly radar was no panacea for force control because radars were not easily relocated, they were strictly line-of-sight, and eventually the enemy developed capabilities to easily jam the radar. Attempts to first exploit the radar resulted in manual control centers. One of the first examples of a manual control center was that of the Strategic Air Command (SAC). SAC's mission required the most advanced command and control system possible. The global nature of SAC's mission made it imperative to meet and solve problems caused by distance, honor the need for clarity and security of instruction, and keep track of thousands of minute details. Large display boards were used to track all force activity. Current positions of all enemy and friendly units were painstakingly plotted. Large display panels, mounted on trolleys, consisted of plastic covered maps and were used by commanders to direct the force. Battle staff technicians plotted new information on these charts as it became available. [Ref.5] Later a switch was made to transparent illuminated plastic display areas where reverse plotting could be accomplished and would not obstruct the view of the force directors. This system of plotting display boards is still used today. This system served its purpose

well; however, it was slow and cumbersome. "Since it represented the apogee of a manual system, automated assistance was imperative." [Ref.5]

In the late 1940's there was a "Black Box" approach to command and control requirements. Equipment was developed and produced for specific applications and little or no consideration was given to environment. Soon black boxes were being designed to interface with black boxes, but the real breakthrough came with the advent of the computer. Now the radar systems could be fully exploited. "The computer could improve the coherence of the radar picture of the air battle by performing many of the processes which humans had been doing imperfectly. Calculation of heading and speed, calculation of intercept solutions, remembering the identity of many moving targets--all of these processes and many more." The first example of computer application coupled with radar (1957) was the Air Force's Semi-Automatic Ground Environment (SAGE) system. This system was a network of radars with communications for connecting and cross-connecting radars to regional control centers and the North American Air Defense headquarters. [Ref.5]

"At the beginning of the 1960's, a committee examining command and control concluded that the capabilities of our weapon systems had outstripped our ability to command and control them. Survivable command centers and rapid, redundant means of communications were being required, with

SAC and the Air Defense Command leading the way." [Ref.6] Additionally, other developments affected force management. The size of a conflict area had clearly expanded beyond line-of-sight and over-the-horizon. Weapons had greater range and capability. Sensor coverage and capabilities overlapped and required coordination for effective use. The coherence of forces depended almost entirely on communications, data processing, and other electronics related functions. Almost concurrently with this surge for more command and control capability came the technological revolution. Rapid technological advances made a significant impact on the development and application of defense related systems.

"By the mid 1960s, we had learned several hard lessons. C3 systems could not be acquired like weapon systems. They had to evolve with continuing user participation." [Ref.6] If we take a moment to stop and review C3 evolution, we recognize that an integral part of good effective C3 is the control of information. What a great information processor the computer was to be. However, there still existed a major stumbling block--defining information needs. Modern computers and communications make it possible to retrieve and/or process an almost infinite amount of information. But, too much information in the system causes great congestion, and too much detail can confuse the decision makers and waste time at a critical point. In spite of these

dangers, the reduction or elimination of validated information requirements continues to be exceptionally difficult. [Ref.6] This process of information distillation or information compression boils down to what does the commander really need? This simple question gives rise to many areas that affect the multi-faceted spectrum of military operations. It became obvious that we needed a system for amalgamating all information inputs and providing commanders with an information display system than was easily evaluated. One aspect of this information display system - tactical situation displays - is addressed by this thesis.

C. PURPOSE

During our C3 Exercise Laboratory (OS3750) class at the Naval Postgraduate School, the authors of this paper participated in a series of experiments which attempted to measure whether or not information processing tasks could be enhanced by presentation of information in color versus monochromatic. These experiments confronted subjects with static naval tactical situation displays. Results of these experiments indicated an improvement in performance when using color displays. As a result of our participation in these experiments, several questions developed regarding symbology for targets. We thought the target symbology used was difficult to immediately recognize. Specifically, these experiments were based on the Navy Tactical Display System

which uses symbology consisting of circular, square, and rhombic shapes to depict targets. Also, we considered that symbols could be tailored to provide more information. The authors experience with military symbols indicated that the daily or constant user of tactical situation displays is able to adapt to the use of non-figurative or abstract symbology, e.g., NTDS symbols. Use of these abstract symbols has been necessitated to date because of equipment limitations. However, with the advance of technology, particularly in the areas of computer driven raster scan devices, it is now possible to tailor symbology to provide more information in a concise manner. With this observation, we postulated that assessment of a tactical situation display may be further enhanced using color figurative symbology. This thesis focuses on improved information content for tactical displays.

II. DESCRIPTION OF EXPERIMENTS

Experiments were conducted to test the null hypothesis that there is no difference between NTDS symbology and figurative symbology. We speculated that descriptive symbology would enhance evaluation of a tactical situation display, i.e., enable the user to more rapidly assimilate and evaluate a tactical situation display. Additionally, the experiments again addressed the issue of whether or not color enhances a subject's ability to assimilate information. This issue was expanded to include an assessment of green/red/white versus blue/orange/white to indicate friendly/hostile/unknown forces.

A. DEFINITIONS

In the context of this paper, references to NTDS symbology are those symbols used in the NTDS system, particularly as used in the Warfare Environment Simulation (WES) game. Circular shapes represent friendly forces, rhombic shapes represent hostile forces, and square shapes represent forces of unknown allegiance (Figure 1).

Monochromatic NTDS displays refer to displays wherein the red and blue electron guns on the graphics display device were disabled. This resulted in a display with a green background and white symbology.

Color NTDS symbology refers to the color symbology used in the WES game. The WES game uses blue to indicate friendly forces, orange to indicate hostile forces, and white to indicate forces of unknown allegiance. Use of color with NTDS symbology results in redundant coding of the symbols allegiance.

"Figurative" symbology refers to lifelike shapes--actual shapes that look like ships, planes, and submarines used to represent targets (Figure 2).

Color figurative (blue/orange) symbology refers to the symbology developed by the authors. The colors (blue, orange, and white) match those used in color NTDS and have the same meaning.

Color figurative (green/red) symbology uses the same symbols as developed for color figurative (blue/orange) but uses green to represent friendly forces and red to represent hostile forces. White again represents unknown forces. Use of green/red/white to represent friendly/hostile/unknown forces was recommended by the authors of GRAPHIC DISPLAYS, A HUMAN ENGINEERING GUIDE FOR USING CRT COMMAND AND CONTROL DISPLAYS. [Ref.7]

"Mode" or "Treatment" refers to monochromatic NTDS, color NTDS, or color figurative display techniques.

B. DESIGN

Two experiments were designed. Their objectives were:

1. To compare response reactions to monochromatic

NTDS displays, color NTDS displays, and color figurative displays.

2. To compare subject's ability to recreate a tactical display from memory.

1. Experiment 1

This experiment was designed to test and compare reaction times to monochromatic NTDS displays, color NTDS displays, color figurative (blue/orange) displays, and color figurative (green/red) displays.

In this experiment, four sets of five tactical situation displays were used (Appendix D). Specifically, these displays were composed of land masses, sea, geographic coordinates, and targets oriented around the aircraft carrier Enterprise(ENTER on displays). Each of the five displays had a different composition of targets and varied in complexity from display 1 (9 symbols) to display 5 (27 symbols). The five displays in each mode were shown in random order. The monochromatic NTDS displays were exact duplicates of the color NTDS displays except that the red and blue electron guns were disabled. The color figurative displays were mimicks of the NTDS displays, i.e., displays were replicated in all particulars except that figurative symbology was presented instead of NTDS symbology. To present the displays and query the subjects, a software routine that had been developed by LCDR Ellen Roland for the OS 3750 class experiment was adapted for this experiment.

The mechanics of the experiment had each subject view four modes of tactical situation displays: monochromatic NTDS, color figurative(blue/orange), color NTDS, and color figurative(green/red). The test was administered to four groups; each group contained six subjects (Appendix A). Order of mode presentation was determined by the subject's group (Appendix B). Each mode contained five tactical situation displays as previously described. Within each mode, order of presentation of displays was randomized to insure the subject received the displays in varying order of complexity for each treatment. Each display was accompanied by six questions (Appendix C). The questions appeared at a terminal that provided immediate feedback. This terminal was separate from the device used to present the tactical situation displays (Figure 3). Questions required that subjects evaluate the display regarding symbol type (aircraft, ship, or submarine) symbol allegiance (friendly, hostile, or unknown) or both (type and allegiance). Questions were repeated until the subject responded correctly. Total time until correct response was recorded for each question. The measure of effectiveness used for evaluation of the displays was total time to correct response for each question.

2. Experiment 2

The second test involved presentation of either a monochromatic NTDS display or a color figurative (green/red)

display for 60 seconds. Subjects were then asked to attempt to reproduce the tactical display from memory. The display was an exact replication of display number two used in experiment 1. The display had eighteen targets with the Enterprise in the center as a reference.

Procedurely, each subject was shown the display and then provided a map (Figure 4) that had target locations marked. Individuals were asked to identify target type and allegiance. Scoring was accomplished by awarding one point for correct identification of target type and one point for correct allegiance. Maximum total points was thirty-six.

The test was administered to two groups, each with twelve subjects (Appendix A). The subjects were the same as those that participated in experiment 1. The groups were randomly structured with no specific criteria of tactical display experience.

C. SUBJECTS

Twenty-four students of the Naval Postgraduate School volunteered as subjects for the experiments. All twenty-four were military officers, 10 from the Air Force, 2 from the Marine Corps, 7 from the Navy, and 5 from the Army. Three of these subjects had extensive previous experience with military display systems; seven had moderate and fourteen had little or no previous experience. Five had previous NTDS experience. All subjects were part of the Command, Control, and Communications curriculum.

Subjects were divided into four groups of six each. This grouping determined the order of presentation of modes. Subjects were placed into groups according to levels of tactical situation display experience. Each group had a relatively equal mix of experience levels to minimize biasing due to previous experience. The order of mode presentation (Appendix B) was changed for each group to minimize confounding due to learning effects.

D. APPARATUS

Each of the subjects was tested using a CONRAC video display (Figure 3) for projecting the tactical display. Adjacent to the video screen, subjects were seated in front of an Ann Arbor terminal (video and keyboard). This equipment is located in the Command, Control and Communications (C3) Laboratory at the Naval Postgraduate School.

E. PROCEDURES

At the start of each trial, subjects were briefed on the purpose and extent of the experiments. Each was acquainted with both NTDS and figurative symbology. Also, the details of question type, display idiosyncrasies, and potential stumbling blocks were explained. Questions addressing the tactical situation displays were presented on the Ann Arbor terminal. Subjects responded to questions by depressing the correct number key followed by a carriage return. If an

incorrect response was made, the question would be repeated until it was answered correctly. When correct, the next question would be displayed. This cycle continued through each display and subsequent mode.

Environmentally, subjects were tested in a darkened area with sufficient lighting to easily read and recognize all displays. Levels of illumination to include brightness, contrast, and color were adjusted on the graphics terminal in order to standardize each trial as nearly as possible.

F. ASSUMPTIONS

Due to resolution limitations of the Genisco graphics device, the size of the figurative symbols did not precisely match the size of the NTDS symbols. However, the slightly larger size of the figurative symbols contributed to a more cluttered display than with the NTDS symbols. These were assumed to be counter-balancing factors.

Also because of equipment resolution limitations, no attempt was made to develop figurative symbology in a monochromatic mode. We assumed that our experimental results would again show that color displays were superior to monochromatic thereby permitting comparison of color figurative versus color NTDS.

The measure of effectiveness (moe) for experiment 1, i.e., subject response time, may not be the ideal method for evaluating tactical situation display presentation techniques. However, response times are measurable

quantities that can be statistically evaluated. Considering that time to analyze a tactical situation, i.e., locate the enemy, is an important military consideration, use of response times as an moe was assumed to be appropriate.

NAVY TACTICAL DISPLAY SYSTEM (NTDS) SYMBOLS

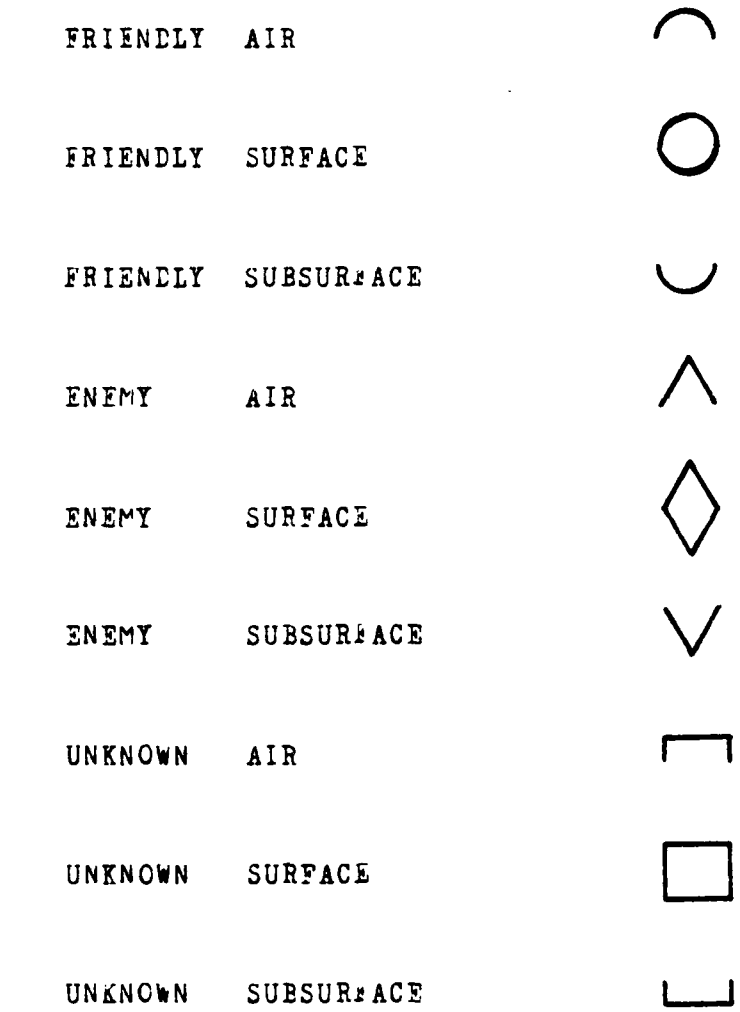


FIGURE 1. NTDS Symbols

FIGURATIVE SYMBOLS

FRIENDLY AIR
(Blue/Green)

FRIENDLY SURFACE
(Blue/Green)

FRIENDLY SUBSURFACE
(Blue/Green)

ENEMY AIR
(Orange/Red)

ENEMY SURFACE
(Orange/Red)

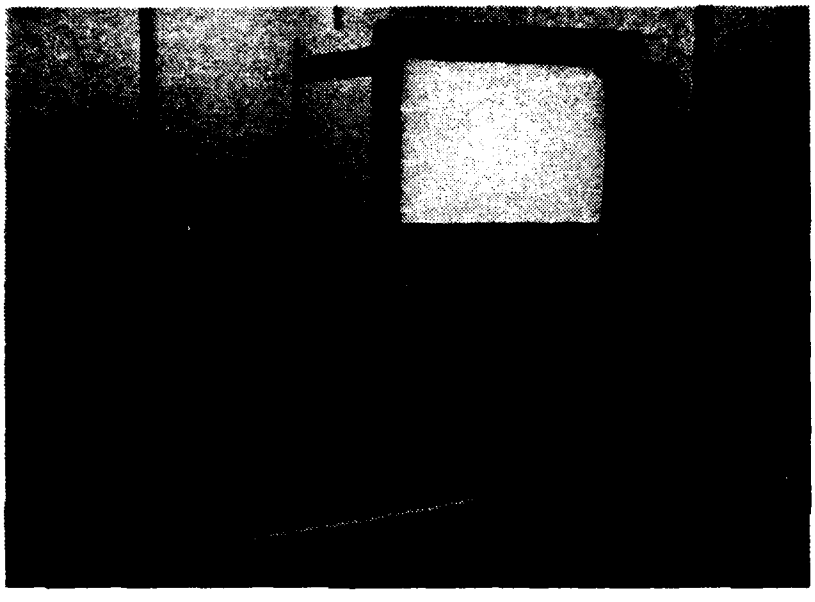
ENEMY SUBSURFACE
(Orange/Red)

UNKNOWN AIR
(White)

UNKNOWN SURFACE
(White)

UNKNOWN SUBSURFACE
(White)

FIGURE 2. Figurative Symbols



ANN ARBCR TERMINAL CCNRAC

Figure 3. Equipment

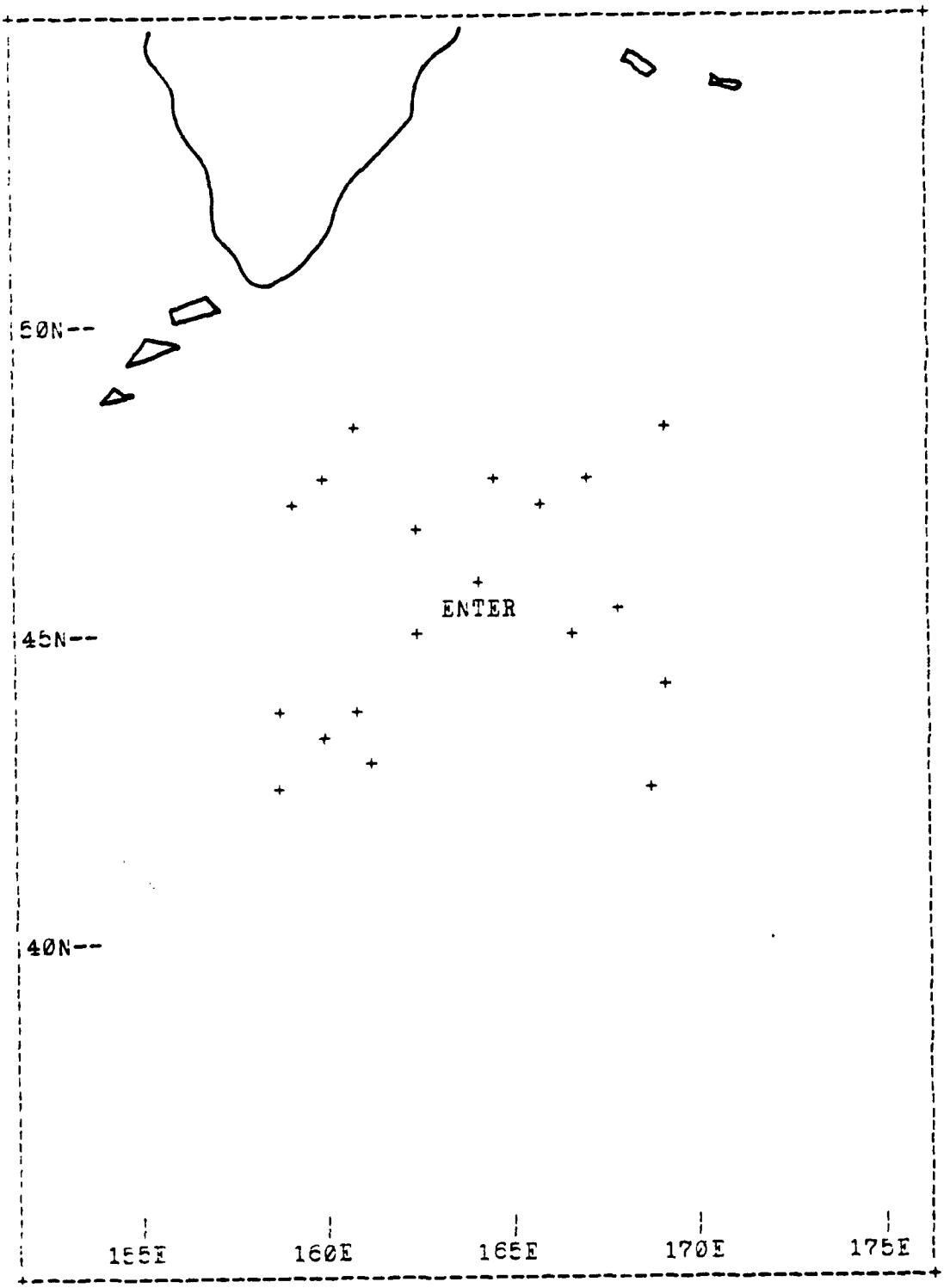


Figure 4. Experiment 2 Map

III. EVALUATION

A. DATA COLLECTION AND REDUCTION

For experiment 1, the subjects' total response times for each question were processed by a computer program and written into data files. This data was then consolidated into a more readable format. Appendix E contains response times broken down by treatment, question, and subject. In some cases, subjects had difficulty understanding the question. This resulted in an unusually high response time. To minimize this skewing effect, those times were discarded in the following manner: the group mean for the other five subjects was calculated and inserted in place of the higher time. In Appendix E these substitutions are shown in parentheses next to the original response time.

Next, the data were further aggregated into the three categories of questions (type, allegiance, or both) by adding the response times for questions of the same category (Figure 5) and then dividing by the number of questions that were added. This resulted in a mean response time per question and category. These data are shown in Appendix F, Table V in conjunction with means and variances computed by group, question, display and treatment. Questions are shown in Appendix C.

DISPLAY #	QUESTION CATEGORIES		
	TYPE	ALLEGIANCE	BOTH
1	1	2,6	3,4,5
2	1,4	2,3,5	6
3	5	2,3,4,6	1
4	5	1,3,6	2,4
5	1,6	3	2,4,5

Figure 5. Question Categories

For experiment 2, each subject's map was scored by awarding one point for correct identification of symbol type and one point for correct allegiance. Maximum score was eighteen in each category for a total of thirty-six points. Appendix G shows the scores.

B. CALCULATIONS OF MEANS AND VARIANCES

Appendix F contains the means and variances of the subjects' response times. Table V shows means and variances by group, question, display and treatment. Table VI contains the means and variances by question, display and treatment. Table VII shows the overall means and variances by question and treatment. Finally, Table VIII contains the grand means and variances by treatment. Means and variances

were calculated by using the fortran computer program listed in Appendix H.

C. ANALYSIS OF EXPERIMENT 1

The analysis of data was done in two parts. First, simple mean and variance statistics were calculated and examined. Then, analysis of variance (ANOVA) [Ref. 8] was used to test for significance of the individual factors and to estimate the effects of the different levels of the factors.

1. Comparison Of Mean Response Times

Comparison of mean response times cannot be considered statistically conclusive because of the large variances involved. However, comparison of means can give one insight into how subjects' performances were affected by display treatments. For example, consider Table V, Monochromatic NTDS Display # 1. Subjects 1-6 (group A) were shown this display treatment first, while subjects 7-12 (group B) saw it last, subjects 13-18 (group C) saw it third, and it was the second display treatment for subjects 19-24 (group D). The improvement of group mean times for questions referring to symbol type, group A-16.33 seconds, group D-12.67 seconds, group C-12.00 seconds, and group B-11.50 seconds, would seem to indicate the presence of learning effects. Likewise, consider Table V, Color NTDS Display # 1. Order of presentation was group C (first),

group B (second), group A (third), and group D (fourth). Mean times for allegiance were C-6.83 seconds, B-6.67 seconds, A-5.75 seconds, and D-4.50 seconds. Again, the presence of learning effects is indicated. Examination of the means by groups and display for the same treatment indicate learning effects for the majority of the displays and questions.

If improvement in response time is due solely to learning effects, than one would expect to see an improvement in the same group's mean times dependent only on order of treatment. Consider group A's performance on display number two. Group A first saw display two in monochromatic NTDS, followed by color figurative (blue/orange), color NTDS, and finally color figurative (green/red). Group mean times for type were 20.33 seconds, 10.17 seconds, 13.25 seconds, and 10.17 seconds. Likewise, consider group C on display number four. Order of treatments was color NTDS, color figurative (green/red), monochromatic NTDS, and color figurative (blue/orange). Mean times for type were 17.17 seconds, 11.67 seconds, 12.67 seconds, and 10.50 seconds. In the majority of displays no clear trend of improvement is evidenced. This suggests that improvement in response times is not based simply on learning effects.

Since for each display and treatment, each group saw the display at a different point in their trials, the means

by question , display and treatment should tend to smooth learning effects of the groups. Table VI contains the overall means by question, display and treatment. For display one, monochromatic NTDS had the slowest mean response times in all three question categories. Also for display one, color figurative (green/red) had the best times for questions referring to symbol type and both, and color NTDS had the third best mean times for type and both. Mean response times for questions referring to allegiance were essentially the same for the three color treatments for all displays. Further examination shows that monochromatic NTDS had the slowest mean response time in every case except one. Color figurative (green/red) had the best time for questions referring to symbol type in every case except for one.

Next, the overall means by question and treatment, shown in Table VII, were considered. Now a clearer picture begins to emerge. Color figurative (green/red) is best in every category of question. For questions referring to symbol type, it is 1.49 seconds better than color figurative (blue/orange), 4.25 seconds better than color NTDS, and 6.33 seconds better than monochromatic NTDS. For questions referring to allegiance, it is 0.18 seconds better than color figurative (blue/orange), 0.61 seconds better than color NTDS, and 6.97 seconds better than monochromatic NTDS. For questions referring to both, color figurative (green/red) is 0.68 seconds better than color figurative

(blue/orange), 0.89 seconds better than color NTDS, and 3.27 seconds better than monochromatic NTDS. For all categories, color figurative (green/red) is best, followed in order by color figurative (blue/orange), color NTDS, and monochromatic NTDS.

Finally, the grand mean for all groups, questions and displays by treatment were calculated. As shown in Table VIII the order of best response times was the same as shown in the preceding paragraph. While these mean response times have been used to gain insight into the subjects' performances, they cannot be considered statistically conclusive because of the variances involved. Also, effects such as learning, display difficulty, and previous experience are not considered. Therefore, a statistically rigorous procedure, analysis of variance, was performed to allow these other potentially important effects to be considered.

2. Analysis of Variance

a. Hypothesis

We hypothesized that figurative symbology would improve operator target recognition times. The experiment null hypothesis was:

$$Ho: M1 = M2 = M3 = M4$$

where M is the mean question response time and 1-4 represent modes monochromatic NTDS, color figurative (blue/orange), color NTDS, and color figurative (green/red), respectively.

The alternate hypothesis is implied--the mean response times for the respective modes are different.

In addition to testing our basic hypothesis, we felt it was important to test for significance of mode/display type interactions and mode/question type interactions.

b. Model

Analysis of variance considered the model:

$$Y(s,d,q)=M+bX1+bX2+As+Bd+Cq+Isd+Isq+Idq+Rsdq$$

where Y(s,d,q) would represent the response to the qth question, dth display, and sth mode. M is the mean response time; bX1 and bX2 represent the two covariables learning and experience; As is the main effect due to mode; Bd is the main effect due to display difficulty; Cq is the main effect due to question format; Isd, Isq, and Idq represent interactions from the main effects; and Rsdq is the residual term. The covariables and the factors, display and question, were included in the model because of our belief that each would affect the response time. Their inclusion in the model allows for a reduction of the error variance making tests of the hypothesis of interest more valid.

In performing the analysis of variance we compiled the data from the twenty four subjects and loaded the data into a file on the Naval Postgraduate School IBM 3033 computer. The data were loaded into a matrix (1440x6)

with information including specific response times to questions, mode type (4 levels), display difficulty (5 levels), question format (3 levels), learning covariable, and the experience covariable. The APL program, ANOVA, was used to calculate the sums of squares, mean squares, degrees of freedom, and the F statistics. The APL program allowed us to first construct the full model as illustrated previously and then reduce this model. With each successive reduction, we were able to eliminate a portion of the full model, test an hypothesis, and determine how much effect each individual factor contributed to the overall model, i.e., how much variability could be attributed to individual pieces.

This model was analyzed to describe all possible elements of variability. The following ANOVA table (Figure 6) dissects the model, illustrating the contributions of individual factors.

The significance levels of the factors in this model make it possible to reject the null hypothesis:

$$Ho: M1 = M2 = M3 = M4$$

Having established that the main effects of the model are significant, we can continue to examine the model to explain which mode presentation was best, which display was easiest, and draw some conclusions about question categories.

ANCVA

SOURCE		DF	SS	MS	F
MODE:	As	3	6421.65	2140.55	106.92
DISPLAY:	Ba	4	6112.88	1528.22	76.33
QUESTIONS:	Ca	2	5252.92	2626.46	131.19
INTERACTIONS					
	Isd	12	1041.07	86.76	4.33
	Isq	6	1220.20	203.37	10.16
	Idq	8	3116.75	389.60	19.46
COVARIABLES					
	bX1	1	268.93	268.93	13.43
	bX2	1	3274.20	3274.20	163.53
RESIDUAL					
	Rsdq	1402	28070.20	20.02	
TOTAL		1439	54783.28		

Figure 6. ANOVA Results

Parameter estimates (Figure 7) were supplied as a by-product of the APL program used. Coefficients for each mode, each display, and each question are noted. The coefficients in each of these groups have been normalized. Specifically, the last element in each of the groups is zero. All other elements of the respective groups are then compared to this zero value. To evaluate these parameters, each was compared to the normalized value.

Analysis of these parameters indicated that color symbology did significantly better than monochromatic. Specifically, the green/red figurative symbology performed best. On the average, questions involving monochromatic displays took 5.5 seconds longer to answer than did those using figurative green/red symbols. (As indicated earlier, questions used for each mode presentation were the same.) Additionally, questions of color NTDS displays took almost 2 seconds longer and questions of figurative blue/orange took .78 of a second longer. As a summary comment, the figurative symbology yielded significantly better results than did monochromatic NTDS, but was only a moderately better performer when color was added. However, it did out-perform the NTDS symbology.

In reviewing the difficulty of displays, the review of the parameter estimates indicates that the easiest display to respond to was display one (nine targets). The most difficult display was display three (twenty-one

targets). This result seemed somewhat inconsistent because display three did not have the most targets. However, this display did have highly clustered symbols, with some overlapping, which made individual target discrimination more difficult. The other displays ranked in order of difficulty according to number of targets.

As an added observation, the parameters for each of the co-variables (Figure 7) is consistent with expected results. Coefficients are negative, which indicates that an individual with more tactical display experience will answer questions more quickly. Also, as individuals were progressively exposed to each of the modes, learning occurred and responses were quicker.

PARAMETER ESTIMATES	
Monochromatic	5.5149
Color Figurative (B/O)	0.7787
Color NTDS	1.9104
Color Figurative (G/R)	0.0
Display 1	-3.1611
Display 2	-1.3862
Display 3	2.9232
Display 4	0.9407
Display 5	0.0
Experience	-0.6100
Learning	-1.3499

Figure 7. Parameter Estimates

c. Summary Of Analysis Of Variance

Two specific observations can be made about Experiment 1. First, addition of color to symbols significantly improved response times to questions about the situation display. Second, figurative symbology performed better than NTDS symbology. Although the proportionate increase is not as great, both sets of color figurative symbology performed better than NTDS. The best performer was the color figurative (green/red) mode.

D. ANALYSIS Of EXPERIMENT 2

1. Comparison of Mean Response Times

The response scores are shown in Appendix G. Means and variances (for n-1 degrees of freedom) were computed. Mean response scores for questions referring to type were: monochromatic - 13.92 and color figurative (green/red) - 14.17. Mean scores for allegiance questions were: monochromatic - 13.42 and figurative - 13.08. Mean total scores were: monochromatic - 27.33 and figurative - 27.25. Examination of the mean scores indicates no difference in performance between the two treatments. To confirm this observation, an analysis of variance was performed.

2. Analysis Of Variance

a. Hypothesis

In this experiment we again hypothesized that figurative symbology would do better than NTDS symbology.

The experiment hypothesis was:

$$Ho: M1 = M2$$

where M is the mean response score for subject's ability to reproduce targets from a timed display and 1-2 represent modes monochromatic and color figurative (green/red).

b. Analysis Of Variance

In doing the analysis on this experiment, we considered the model:

$$Y(d,q) = M + bX1 + Ad + Bq + Idq + Rdq$$

where Y(d,q) would represent the score of subject; bX1 is a covariable representing experience; Ad is a main effect due to mode, monochromatic or color figurative green/red; Bq is a main effect due to question type, either a type target question or an allegiance question; and Rsd is the residual term.

Analysis was accomplished with an APL program. The data were loaded into a matrix (48 x 4) with information including specific scores of individuals, mode, question category (type or allegiance), and an experience covariable. With the APL program, we were able to structure an ANOVA model and then, through successive reductions of the model, we were able to determine contributions of individual effects to the total variability within the model.

ANOVA			
SOURCE	DF	SS	F
MONO/COLOR	1	1.50	.22
QUESTION	1	7.04	1.01
M/C x Q	1	.18	.03
COV 1	1	11.34	1.63
RESIDUAL	43	299.07	
TOTAL	47	329.81	

Figure 8. ANOVA Results

Figure 8 contains the ANOVA table which indicates that none of the effects within this model were significant. The null hypothesis cannot be rejected.

IV. DISCUSSION AND CONCLUSIONS

A. CONCLUSIONS

This research effort was directed at determining the utility of figurative symbology for use in tactical situation displays. Results of experiment one confirmed the advantage of using color versus monochromatic displays. Additionally, the advantage of using figurative versus NTDS symbols was demonstrated by experiment one. Whereas experiment one addressed tasks involving speed of target recognition, we conclude that use of color figurative symbologies in military tactical situation displays merits further investigation.

Experiment two addressed utility of color versus monochromatic displays in tasks involving memory of target location. Results of experiment two do not support use of color figurative displays in situations that require memorization of displays. This result is attributed to the redundant coding of the NTDS symbology. Subjects had to memorize only symbol shape in order to remember both symbol type and allegiance when viewing the monochromatic NTDS display. The color figurative symbology required memorization of both symbol shape and color in order to remember type and allegiance. One may postulate that the color figurative subjects were actually processing more

information, i.e., processing more mental bits than those that viewed the monochromatic displays. If true, one could then conclude that the color figurative test subjects had to outperform the monochromatic test subjects in order to achieve the same mean scores. Further investigation of this possibility is left for future study.

B. DISCUSSION OF FUTURE SYSTEMS

Nowhere is the need for accurate, up to the minute and easily comprehensible information more necessary than in a conflict situation. The ability to sort out and interpret information quickly is of the utmost importance. Because of the military's large data bases, the amount of information available to commanders is immense. The use of computer graphics to display data allows the commander to get maximum information. The high information content in a graphic display will enable the operator to assimilate more data with far less fatigue. Also, the ability to update the data instantaneously on the screen gives the commander the most current information available to aid in his decision-making process. [Ref. 9]

As noted previously, symbology used in tactical situation displays has been limited by technology. However, the technology now exists to develop computer graphic display symbology that can be tailored to meet specific user needs. Why not fully exploit this capability? Although not illustrated specifically in this thesis, potential does

exist now for developing even more descriptive symbology than was developed by the authors. Just visit your local game arcade and take a close look at the electronic games. The level of symbol detail available in these devices is ahead of most current military display systems. To continue to provide commanders with efficient display systems, the military must take advantage of these advances in technology.

APPENDIX A

SUBJECT GROUPINGS

SUBJ #	EXPERIMENT 1 GROUPS			
	A	B	C	D
1	LIND	7 FRENCH	13 BENT	19 w. LENAHAN
2	SIMON	8 D. LENAHAN	14 WREN	20 MCLENDON-KOENIG
3	HOPPER	9 VANHOY	15 GRAHAM	21 REESE
4	WELT	10 ALLEN	16 ALLGOOD	22 FOTHERINGHAM
5	JOHNSON	11 EISENTROUT	17 MCDANIEL	23 MOTZ
6	SCHAEFER	12 SMART	18 WESTON	24 RUESS

EXPERIMENT 2 GROUPS			
MONOCHROMATIC NTDS MAP		COLOR FIGURATIVE(G/R) MAP	
LIND	ALLGOOD	WESTON	ALLEN
FRENCH	FOTHERINGHAM	D. LENAHAN	GRAHAM
BENT	EISENTROUT	W. LENAHAN	MCLENDON-KOENIG
SIMON	MCDANIEL	MOTZ	SCHAEFER
HOPPER	REESE	VANHOY	JOHNSON
WELT	RUESS	WREN	SMART

APPENDIX B

ORDER OF TREATMENTS BY GROUP

GROUP A

First run - Monochromatic NTDS
Second run - Color Figurative(blue/orange)
Third run - Color NTDS
Fourth run - Color Figurative(green/red)

GROUP B

First run - Color Figurative(blue/orange)
Second run - Color NTDS
Third run - Color Figurative(green/red)
Fourth run - Monochromatic NTDS

GROUP C

First run - Color NTDS
Second run - Color Figurative(green/red)
Third run - Monochromatic NTDS
Fourth run - Color Figurative(blue/orange)

GROUP D

First run - Color Figurative(green/red)
Second run - Monochromatic NTDS
Third run - Color Figurative(blue/orange)
Fourth run - Color NTDS

APPENDIX C

EXPERIMENT 1 QUESTIONS

DISPLAY 1
Question 1: How many air units are displayed?
Question 2: How many friendly units are displayed?
Question 3: How many enemy submarines are displayed?
Question 4: How many units are west of the Enterprise?
Question 5: How many enemy air units are displayed?
Question 6: Which quadrant has the largest concentration of enemy units?

DISPLAY 2
Question 1: How many air units are displayed?
Question 2: How many friendly units are displayed?
Question 3: How many enemy units are in the quadrant with the greatest concentration of enemy units?
Question 4: How many submarines are displayed?
Question 5: How many units are northeast of the Enterprise excluding friendly units?
Question 6: How many unknown air units are displayed?

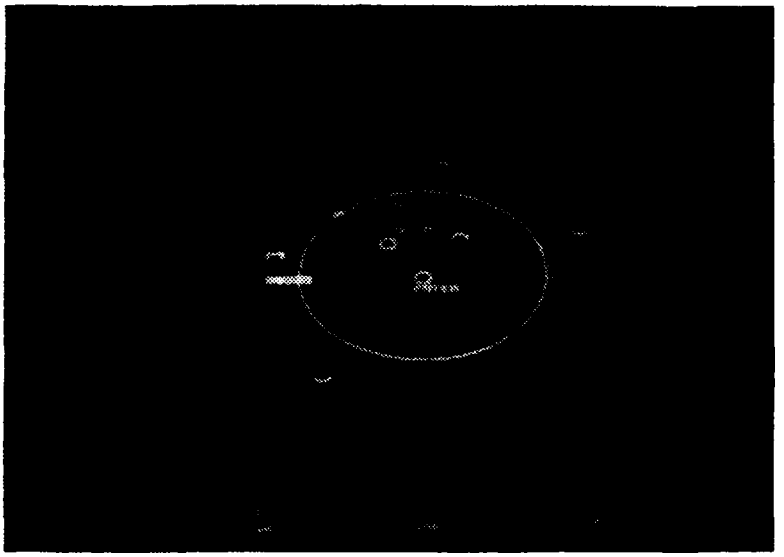
DISPLAY 3
Question 1: How many enemy surface units are displayed?
Question 2: How many friendly units are displayed?
Question 3: How many friendly units are in the quadrant containing the largest number of friendly units?
Question 4: How many unknown units are displayed?
Question 5: How many air units are displayed?
Question 6: How many units are northeast of the Enterprise excluding friendly units?

DISPLAY 4
Question 1: How many enemy units are displayed?
Question 2: How many friendly air units are displayed?
Question 3: How many enemy units are in the quadrant with the greatest concentration of enemy units?
Question 4: How many unknown surface units are displayed?
Question 5: How many subsurface units are displayed?
Question 6: How many friendly units are displayed?

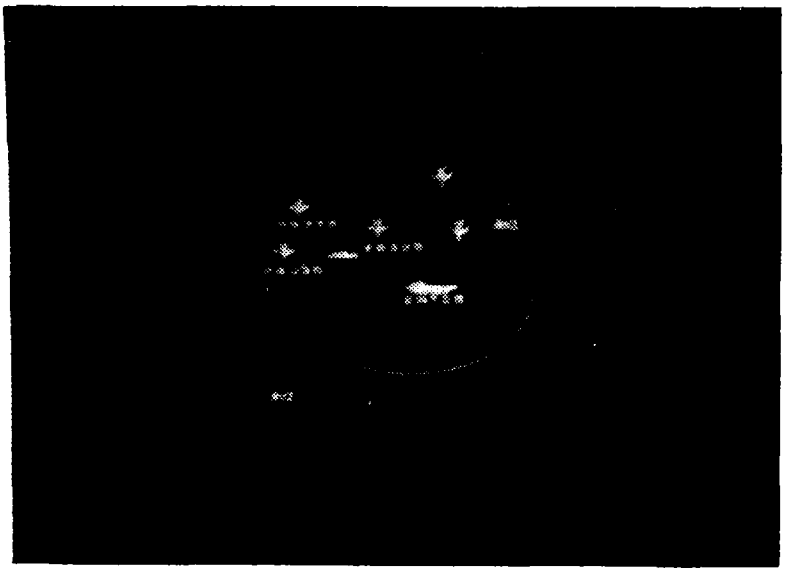
DISPLAY 5
Question 1: How many surface units are displayed?
Question 2: How many friendly air units are north of the Enterprise?
Question 3: How many unknown units are displayed?
Question 4: How many friendly surface units are displayed?
Question 5: How many enemy surface units are in the NW quadrant?
Question 6: How many submarines are displayed?

APPENDIX D

DISPLAY 1

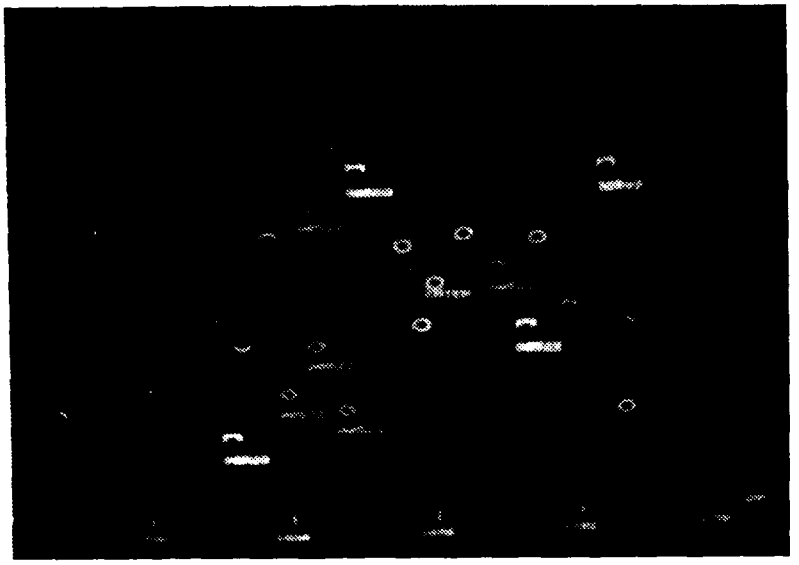


NTDS

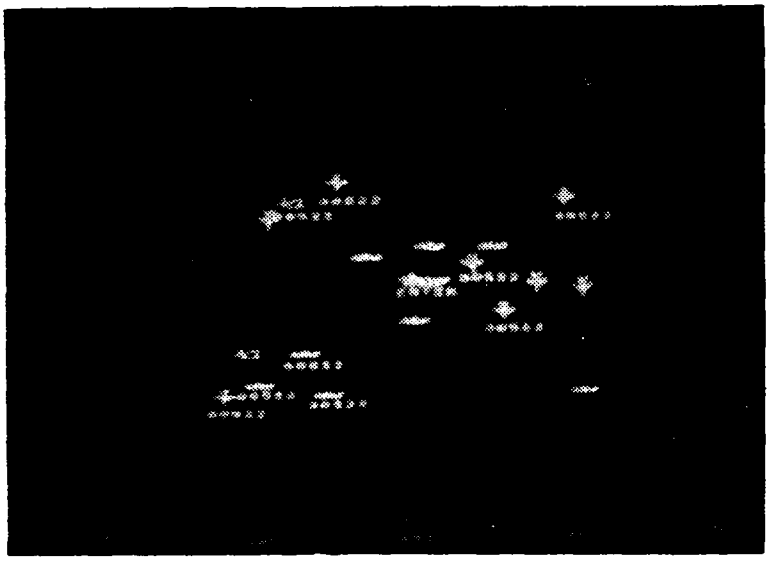


FIGURATIVE

DISPLAY 2

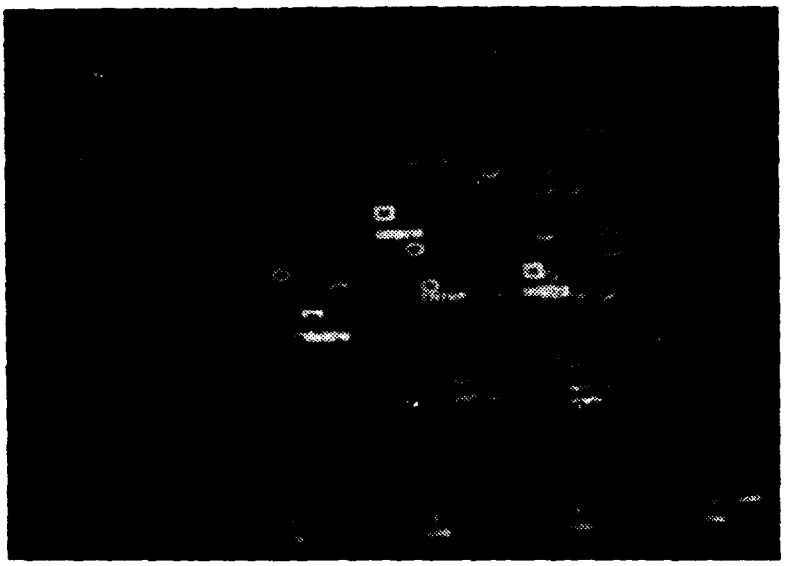


NTDS



FIGURATIVE

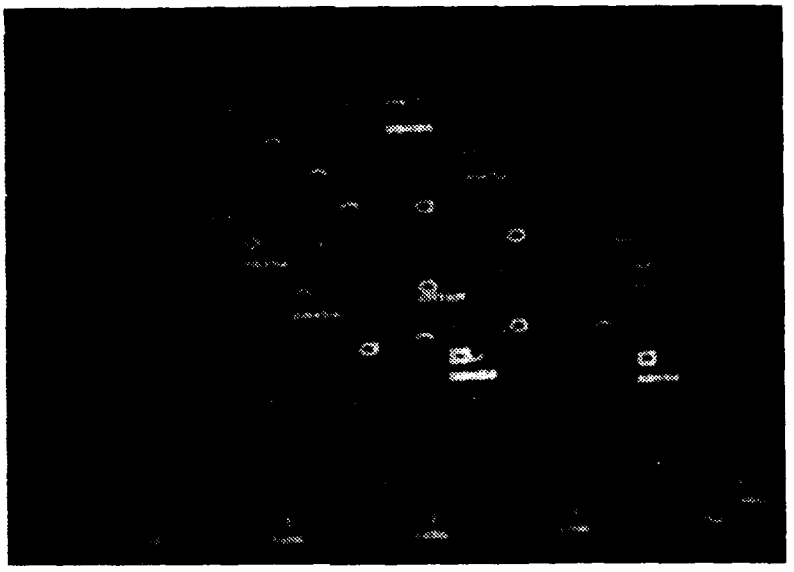
DISPLAY 3



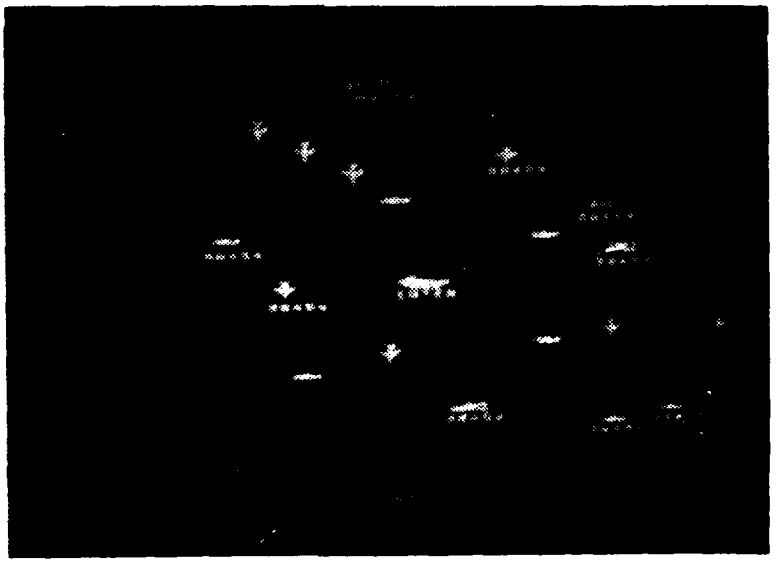
NTDS

FIGURATIVE

DISPLAY 4

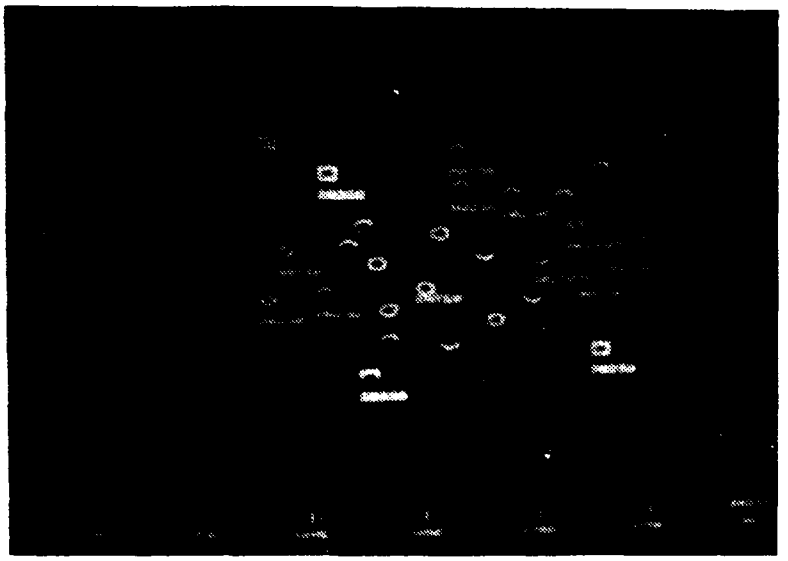


NTDS

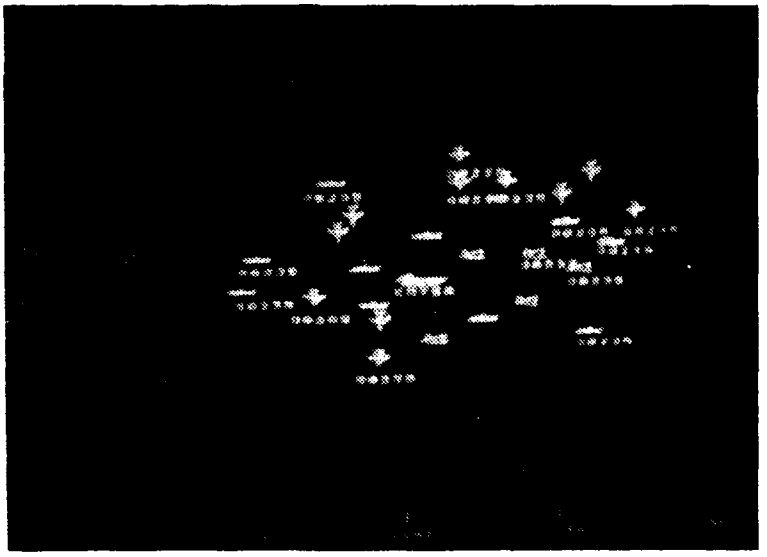


FIGURATIVE

DISPLAY 5



NTDS



FIGURATIVE

APPENDIX I

EXPERIMENT 1 RESPONSE TIMES

TABLE I-a

MONOCHROMATIC NTDS RESPONSE TIMES

DISPLAY 1						
question	1	2	3	4	5	6
subject						
1	8	7	7	7	5	10
2	30	16	8	17	8	11
3	21	9	13	8	8	20
4	16	7	7	7	12	11
5	15	11	7	11	9	20
6	8	11	22	7	10	9
7	7	12	6	8	5	7
8	17	11	6	4	4	6
9	18	8	7	5	4	5
10	8	6	6	5	6	6
11	7	6	5	5	5	6
12	12	17	11	10	7	10
13	16	7	7	9	8	10
14	10	13	8	5	16	4
15	8	6	5	5	6	6
16	12	6	12	6	14	6
17	9	6	4	7	4	6
18	17	7	6	4	5	4
19	6	5	5	7	6	6
20	25	7	9	8	7	6
21	5	5	5	4	7	6
22	6	18	11	6	15	8
23	17	16	20	9	11	22
24	17	19	12	6	9	9

TABLE I-b

MONOCHROMATIC NTDS RESPONSE TIMES

DISPLAY 2						
question	1	2	3	4	5	6
subject						
1	12	12	13	8	10	6
2	28	12	21	34	9	9
3	27	25	16	8	13	5
4	19	32	29	27	19	16
5	33	29	17	17	21	7
6	13	17	24	83(18)	13	13
7	35	13	11	15	7	4
8	9	10	18	7	8	6
9	17	23	14	12	7	9
10	14	9	7	15	9	6
11	17	14	8	8	6	5
12	15	17	13	11	7	11
13	13	13	17	23	10	5
14	15	14	10	10	7	7
15	11	14	11	10	8	5
16	10	19	7	9	10	5
17	11	10	8	9	5	5
18	32	26	18	11	10	5
19	9	15	24	9	8	5
20	21	13	15	11	8	7
21	25	15	9	10	10	6
22	32	22	16	10	9	5
23	131(21)	32	22	23	12	12
24	17	16	22	23	27	15

TABLE I-c

MONOCHROMATIC NTDS RESPONSE TIMES

DISPLAY 3						
question	1	2	3	4	5	6
subject						
1	24	24	19	10	47	20
2	24	98(21)	22	19	39	54
3	20	27	123(29)	12	9	16
4	15	17	33	10	19	22
5	22	19	54	22	24	45
6	16	19	16	11	17	17
7	17	12	34	4	25	15
8	14	10	33	6	10	9
9	11	32	16	12	22	11
10	16	17	34	9	17	17
11	13	12	9	10	15	14
12	11	11	21	10	50	22
13	17	14	20	7	24	14
14	13	16	38	8	19	10
15	11	12	13	10	17	8
16	11	21	41	9	11	14
17	9	13	15	7	37	10
18	29	14	13	6	19	20
19	15	16	24	11	17	10
20	17	24	18	10	50	11
21	10	16	11	6	11	39
22	21	57(22)	21	6	10	22
23	16	80(22)	67	11	40	29
24	15	32	27	65(9)	27	45

TABLE I-d

MONOCHROMATIC NTDS RESPONSE TIMES

DISPLAY 4						
question	1	2	3	4	5	6
subject						
1	33	11	22	7	11	21
2	18	12	18	7	17	16
3	21	23	145(32)	5	11	23
4	19	19	38	11	32	60
5	27	21	30	10	32	49
6	72(24)	10	52	12	18	27
7	14	8	11	6	9	88(15)
8	10	10	14	6	8	10
9	25	16	17	10	14	78(15)
10	13	11	20	5	11	12
11	15	11	15	8	10	15
12	14	12	17	10	13	23
13	22	11	36	7	13	34
14	14	12	11	7	10	64(19)
15	38	16	16	6	12	22
16	30	10	15	6	15	14
17	12	17	22	6	10	12
18	14	9	15	7	16	13
19	11	10	8	6	9	32
20	20	13	14	13	20	17
21	22	8	14	4	9	10
22	14	11	67(16)	9	11	29
23	52	33	22	9	63(15)	31
24	20	34	25	16	24	63(24)

TABLE I-e

MONOCHROMATIC NIDS RESPONSE TIMES

DISPLAY 5						
question	1	2	3	4	5	6
subject						
1	13	10	9	14	12	11
2	22	13	12	10	34	12
3	12	22	11	9	7	24
4	18	49(16)	13	10	12	99(18)
5	19	21	14	10	16	28
6	64(17)	15	23	9	25	14
7	29	9	5	9	8	8
8	8	8	9	5	7	8
9	17	13	11	28	7	12
10	9	9	11	7	7	10
11	10	8	7	9	6	11
12	14	13	10	10	11	13
13	17	18	5	12	10	13
14	13	28	8	7	9	17
15	14	10	7	16	7	10
16	10	18	11	13	29	26
17	12	11	9	6	6	9
18	15	10	6	13	9	19
19	44	22	9	6	9	10
20	14	11	13	7	22	14
21	11	9	4	5	8	10
22	13	11	8	12	9	20
23	34	19	22	13	19	19
24	13	27	46	11	14	24

TABLE II-a

COLOR FIGURATIVE (BLUE/ORANGE) RESPONSE TIMES

DISPLAY 1						
question	1	2	3	4	5	6
subject						
1	7	6	5	5	4	6
2	9	4	5	11	6	17
3	6	14	8	10	5	5
4	6	7	5	7	6	7
5	6	5	8	14	4	5
6	8	6	6	7	8	4
7	13	7	6	8	3	6
8	15	7	10	10	5	7
9	33	10	7	10	7	8
10	12	8	20	15	8	10
11	8	4	10	9	5	5
12	10	7	8	9	10	10
13	7	5	8	7	4	6
14	5	5	5	6	5	2
15	7	5	5	3	3	3
16	4	4	4	5	5	3
17	7	6	3	4	5	3
18	6	5	5	9	4	3
19	6	5	4	6	4	3
20	6	4	4	5	3	3
21	4	4	4	10	4	3
22	5	7	4	9	4	4
23	11	7	6	6	6	4
24	9	6	5	6	4	3

TABLE II-b

COLOR FIGURATIVE (BLUE/ORANGE) RESPONSE TIMES

DISPLAY 2						
question	1	2	3	4	5	6
subject						
1	8	8	6	9	9	6
2	6	7	7	4	10	4
3	10	16	6	5	6	9
4	11	12	9	9	11	6
5	23	11	6	20	11	5
6	9	9	8	8	9	5
7	14	36	12	8	21	13
8	11	16	9	8	11	5
9	11	12	7	9	8	6
10	10	8	8	6	8	5
11	9	11	6	9	7	4
12	12	13	12	9	16	6
13	8	10	9	6	8	4
14	7	8	4	7	5	4
15	6	7	4	6	5	4
16	7	7	5	5	6	3
17	7	7	6	6	7	4
18	7	9	4	6	9	5
19	6	9	6	10	5	4
20	5	6	5	5	5	4
21	6	6	2	5	5	3
22	8	7	7	8	6	6
23	10	10	8	9	7	6
24	12	10	11	9	12	10

TABLE II-c

COLOR FIGURATIVE (BLUE/ORANGE) RESPONSE TIMES

DISPLAY 3						
question	1	2	3	4	5	6
subject						
1	11	11	23	7	8	12
2	17	10	28	8	7	10
3	13	11	21	9	19	11
4	12	9	17	6	10	18
5	12	9	18	7	13	18
6	23	12	8	5	23	128(14)
7	14	19	14	5	11	11
8	15	14	18	10	11	15
9	8	17	28	7	10	15
10	16	12	25	9	12	115(15)
11	37	9	13	30	33	20
12	18	17	43	18	11	97(15)
13	22	10	15	7	10	11
14	5	8	8	3	11	7
15	10	6	8	15	11	8
16	6	9	11	7	15	11
17	8	6	8	3	9	6
18	16	10	9	7	6	11
19	6	7	7	3	10	15
20	9	8	10	8	8	67(15)
21	9	9	7	6	10	5
22	13	8	8	4	8	11
23	13	11	22	5	9	18
24	9	7	28	5	13	24

TABLE II-d

COLOR FIGURATIVE (BLUE/ORANGE) RESPONSE TIMES

DISPLAY 4						
question	1	2	3	4	5	6
subject						
1	10	7	8	8	12	14
2	10	6	11	4	9	9
3	6	9	7	6	8	9
4	9	19	11	27	12	13
5	9	7	9	7	13	12
6	10	8	11	7	18	13
7	6	6	7	6	18	11
8	11	14	7	7	18	19
9	8	6	11	6	12	32
10	18	10	15	24	37	17
11	7	8	9	6	13	11
12	17	13	19	8	31	27
13	12	6	15	5	24	11
14	6	7	5	8	8	9
15	9	7	8	6	7	12
16	5	7	6	6	9	14
17	12	6	6	3	7	8
18	7	6	7	7	8	20
19	6	6	5	5	8	11
20	6	8	8	4	14	9
21	8	6	5	3	7	8
22	6	12	7	4	9	9
23	9	9	9	6	10	11
24	7	6	11	8	13	11

TABLE II-e

COLOR FIGURATIVE (BLUE/ORANGE) RESPONSE TIMES

DISPLAY 5						
question	1	2	3	4	5	6
subject						
1	16	17	6	9	11	10
2	19	6	4	8	9	10
3	39	6	5	15	8	10
4	21	10	5	8	9	8
5	33	7	4	12	9	17
6	14	9	4	14	8	8
7	24	6	6	9	8	37
8	30	9	6	7	13	12
9	36	8	6	8	8	9
10	24	12	5	11	21	11
11	20	10	8	19	7	10
12	60	13	9	12	24	30
13	36	8	4	8	9	16
14	11	8	3	11	6	8
15	15	4	5	7	6	8
16	10	8	8	6	6	6
17	11	5	4	7	4	6
18	12	6	4	8	7	7
19	11	10	4	7	7	19
20	23	5	4	10	6	15
21	9	5	4	8	9	6
22	21	7	4	14	7	6
23	17	7	5	7	21	12
24	16	7	4	13	18	7

TABLE III-a

COLOR NTDS RESPONSE TIMES

DISPLAY 1						
question	1	2	3	4	5	6
subject						
1	7	6	11	7	4	6
2	11	4	6	5	5	6
3	11	5	7	4	6	5
4	15	7	5	9	6	7
5	12	6	7	6	9	4
6	13	5	8	6	5	8
7	18	11	7	7	4	5
8	5	4	5	5	4	10
9	18	7	8	6	6	5
10	9	6	8	10	5	5
11	8	5	7	5	3	5
12	12	9	8	24	15	7
13	8	7	7	16	11	9
14	11	9	7	9	14	4
15	12	5	5	7	4	4
16	13	6	8	9	5	5
17	7	6	4	5	4	15
18	9	6	9	11	5	6
19	5	4	5	3	4	3
20	14	3	5	5	3	3
21	6	6	3	6	4	4
22	7	5	6	19	4	4
23	17	6	12	7	13	6
24	9	6	14	7	4	4

TABLE III-b

COLOR NTDS RESPONSE TIMES

DISPLAY 2						
question	1	2	3	4	5	6
subject						
1	10	12	9	7	7	6
2	40(16)	7	8	5	5	6
3	17	9	5	11	9	11
4	12	10	7	18	9	7
5	21	10	7	12	7	5
6	22	7	9	8	6	7
7	63(15)	11	10	12	6	4
8	17	6	6	8	8	5
9	17	15	15	13	9	6
10	13	13	9	9	9	9
11	16	14	10	15	16	5
12	12	11	11	19	11	9
13	15	15	14	26	20	7
14	12	11	12	23	19	6
15	19	20	7	10	11	6
16	32(20)	10	9	9	9	5
17	31	9	5	11	7	8
18	23	8	8	10	8	12
19	8	7	6	6	7	4
20	9	5	5	7	6	5
21	12	8	6	7	7	10
22	20	10	5	6	7	9
23	11	8	7	11	9	5
24	14	8	11	11	7	8

TABLE III-c

COLOR NTDS RESPONSE TIMES

DISPLAY 3						
question	1	2	3	4	5	6
subject						
1	21	10	12	8	58(19)	23
2	11	7	14	6	23	8
3	21	8	15	6	18	14
4	8	12	13	5	24	20
5	9	8	12	7	16	28
6	17	8	14	7	13	17
7	9	9	14	6	21	14
8	8	7	9	6	15	10
9	9	14	14	6	16	12
10	10	7	13	5	21	20
11	13	9	11	3	14	32
12	9	28(9)	16	11	12	18
13	11	16	17	7	38	19
14	10	10	14	6	28	13
15	10	14	15	9	11	11
16	16	23	12	8	14	31
17	6	25	12	6	9	9
18	12	23	15	12	70(20)	44
19	10	20	10	3	8	11
20	6	6	23	5	21	7
21	7	8	7	4	23	16
22	6	6	17	5	10	9
23	17	31	10	7	20	27
24	10	9	9	5	33(16)	9

TABLE III-a

COLOR NTDS RESPONSE TIMES

DISPLAY 4						
question	1	2	3	4	5	6
subject						
1	8	8	8	6	15	10
2	9	61(11)	10	5	6	7
3	8	8	7	4	17	9
4	7	21	11	7	14	7
5	10	9	11	6	13	8
6	8	10	12	5	22	9
7	9	9	9	5	15	10
8	6	7	8	5	8	7
9	12	14	8	6	11	27
10	6	8	11	6	14	9
11	9	15	14	7	16	13
12	19	11	31	9	21	10
13	9	11	17	5	23	14
14	7	11	11	5	11	10
15	7	16	16	6	11	8
16	7	15	38	10	14	13
17	8	7	12	5	16	9
18	10	8	11	7	26	12
19	7	8	13	4	12	8
20	5	8	14	9	12	6
21	7	8	9	4	9	8
22	24	12	10	7	10	10
23	10	9	13	5	14	12
24	7	9	19	6	15	9

TABLE III-e

COLOR NTDS RESPONSE TIMES

DISPLAY 5						
question	1	2	3	4	5	6
subject						
1	19	8	6	8	8	10
2	13	13	4	9	13	11
3	14	6	6	8	9	15
4	19	9	5	8	8	30
5	21	6	4	10	14	17
6	30	14	5	7	7	36
7	22	7	6	9	10	23
8	18	7	6	6	10	8
9	16	9	5	7	7	14
10	59(17)	19	6	15	14	13
11	15	5	4	14	11	11
12	15	14	8	9	15	14
13	36	28	7	115(8)	77(14)	32
14	13	10	5	10	11	17
15	32	12	5	7	11	13
16	15	16	10	11	24	19
17	11	7	8	4	12	19
18	11	12	6	6	10	24
19	9	11	5	6	6	8
20	10	7	3	4	7	18
21	8	12	3	5	7	9
22	10	13	5	15	8	17
23	14	11	8	6	12	12
24	13	8	8	9	9	10

TABLE IV-a

COLOR FIGURATIVE (GREEN/RED) RESPONSE TIMES

DISPLAY 1						
question	1	2	3	4	5	6
subject						
1	8	6	7	7	5	6
2	6	11	4	4	5	5
3	5	7	4	4	3	4
4	6	7	6	6	4	5
5	8	5	6	6	6	3
6	5	4	5	5	5	4
7	9	18	5	7	4	5
8	5	5	4	5	4	4
9	10	5	12	5	4	4
10	7	4	6	7	3	3
11	10	8	4	4	4	6
12	9	6	9	6	5	6
13	9	7	6	7	4	6
14	7	5	5	8	6	4
15	6	8	7	4	4	2
16	6	6	5	6	4	5
17	3	4	3	4	4	5
18	6	6	5	6	4	7
19	10	4	6	23(6)	4	5
20	10	6	4	6	3	6
21	14	6	25	6	8	11
22	7	8	5	4	5	6
23	30(9)	37(5)	10	9	5	15
24	6	6	5	7	5	6

TABLE IV-b

COLOR FIGURATIVE (GREEN/RED) RESPONSE TIMES

DISPLAY 2						
question	1	2	3	4	5	6
subject						
1	19	13	9	6	8	5
2	9	7	16	5	6	3
3	16	9	4	5	7	4
4	9	10	8	7	9	6
5	18	12	7	13	10	5
6	10	10	7	8	14	5
7	8	21	6	8	7	5
8	5	7	5	5	6	5
9	8	9	6	8	42(7)	8
10	12	7	5	5	7	4
11	11	8	5	7	7	4
12	9	13	8	16	10	7
13	11	11	14	8	12	5
14	9	8	5	6	9	7
15	13	18	4	8	6	5
16	12	6	9	5	9	4
17	15	9	6	7	15	5
18	10	11	18	14	17	5
19	11	16	10	8	9	6
20	24	7	5	5	9	7
21	6	11	5	5	10	4
22	8	12	6	8	7	5
23	15	25	15	9	22	7
24	10	8	7	14	12	7

TABLE IV-c

COLOR FIGURATIVE (GREEN/RED) RESPONSE TIMES

DISPLAY 3						
question	1	2	3	4	5	6
subject						
1	15	11	10	7	11	9
2	12	10	10	3	6	9
3	7	7	9	4	16	12
4	8	9	14	5	10	20
5	10	8	11	4	13	9
6	12	7	8	5	9	12
7	7	9	11	5	9	16
8	7	6	9	4	6	9
9	7	12	11	5	11	8
10	8	6	16	6	6	11
11	14	12	6	3	12	14
12	10	19	12	7	9	16
13	41(10)	65(7)	28(10)	6	11	127(11)
14	8	8	8	4	8	13
15	6	7	9	13	10	11
16	11	8	9	6	7	11
17	6	6	8	5	9	7
18	17	8	18	5	20	14
19	11	8	12	4	10	10
20	9	7	11	4	9	48(14)
21	7	6	10	4	6	9
22	7	8	9	4	9	15
23	16	11	21	5	15	21
24	20	21	13	8	11	16

TABLE IV-d

COLOR FIGURATIVE (GREEN/RED) RESPONSE TIMES

DISPLAY 4						
question	1	2	3	4	5	6
subject						
1	7	9	7	6	10	15
2	24(10)	11	6	5	6	35(14)
3	5	5	8	4	11	15
4	7	15	8	7	23	14
5	18	12	7	13	10	5
6	8	6	5	14	9	15
7	6	7	6	5	9	10
8	6	4	7	6	6	16
9	7	8	8	6	9	12
10	6	7	5	5	8	31
11	6	7	5	4	9	9
12	10	20	14	7	11	19
13	13	30	18	6	10	14
14	10	9	6	4	18	38
15	7	9	7	6	10	9
16	7	5	7	7	10	22
17	6	6	7	5	7	12
18	8	8	8	7	15	13
19	7	16	8	4	13	14
20	8	7	12	5	42(13)	23
21	6	5	7	4	13	9
22	8	9	16	7	12	21
23	14	23	35(12)	55(6)	14	20
24	11	11	19	10	64(13)	23

TABLE IV-e

COLOR FIGURATIVE (GREEN/RED) RESPONSE TIMES

DISPLAY 5						
question	1	2	3	4	5	6
subject						
1	13	11	5	11	7	10
2	9	7	3	12	8	8
3	14	5	4	9	7	7
4	16	10	5	10	15	9
5	14	7	4	10	9	9
6	24	13	4	10	8	9
7	24	7	5	15	10	10
8	38	11	4	7	8	7
9	60(21)	8	7	8	5	8
10	11	6	4	7	6	6
11	18	8	3	7	5	10
12	12	8	5	8	17	14
13	42(13)	8	5	7	9	10
14	15	5	4	7	7	11
15	12	6	4	8	8	8
16	44(13)	9	8	8	18	10
17	13	6	4	6	7	12
18	11	8	5	11	7	9
19	48(25)	9	5	11	13	10
20	57(25)	9	5	16	41(17)	8
21	21	7	3	5	7	6
22	26	9	4	6	8	7
23	88(25)	11	5	12	36	14
24	28	9	10	11	23	12

APPENDIX F

EXPERIMENT 1 MEANS AND VARIANCES

TABLE V-a
MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT
MONOCHROMATIC NTDS DISPLAY # 1

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	8.00	8.50	6.33
2	30.00	13.50	11.00
3	21.00	14.50	9.67
4	16.00	9.00	8.67
5	15.00	15.50	9.00
6	8.00	10.00	13.00
GROUP MEAN =	16.33	11.83	9.61
GROUP VARIANCE =	69.87	9.17	5.09
7	7.00	9.50	6.33
8	17.00	8.50	4.67
9	18.00	6.50	5.33
10	8.00	6.00	5.67
11	7.00	6.00	5.00
12	12.00	13.50	9.33
GROUP MEAN =	11.50	8.33	6.06
GROUP VARIANCE =	25.10	8.47	2.90
13	16.00	8.50	8.00
14	10.00	8.50	9.67
15	8.00	6.00	5.33
16	12.00	6.00	10.67
17	9.00	6.00	5.00
18	17.00	5.50	5.00
GROUP MEAN =	12.00	6.75	7.28
GROUP VARIANCE =	14.00	1.88	6.38
19	6.00	5.50	6.00
20	25.00	6.50	8.00
21	5.00	5.50	5.33
22	6.00	13.00	10.67
23	17.00	19.00	13.33
24	17.00	14.00	9.00
GROUP MEAN =	12.67	10.58	8.72
GROUP VARIANCE =	67.47	31.34	8.91
QUESTION MEAN =	13.12	9.38	7.92
QUESTION VARIANCE =	42.11	15.09	6.99
DISPLAY MEAN =	10.14		
DISPLAY VARIANCE =	25.68		

TABLE V-b

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR FIGURATIVE (BLUE/ORANGE) DISPLAY # 1

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	7.00	6.00	4.67
2	9.00	10.50	7.33
3	6.00	9.50	7.67
4	6.00	7.00	6.00
5	6.00	5.00	8.67
6	8.00	5.00	7.00
GROUP MEAN =	7.00	7.17	6.89
GROUP VARIANCE =	1.60	5.47	1.94
7	13.00	6.50	5.67
8	15.00	7.00	8.33
9	33.00	9.00	8.00
10	12.00	9.00	14.33
11	8.00	4.50	8.00
12	10.00	8.50	9.00
GROUP MEAN =	15.17	7.42	8.89
GROUP VARIANCE =	82.17	3.14	8.37
13	7.00	5.50	6.33
14	5.00	3.50	5.33
15	7.00	4.00	3.67
16	4.00	3.50	4.67
17	7.00	4.50	4.00
18	6.00	4.00	6.00
GROUP MEAN =	6.00	4.17	5.00
GROUP VARIANCE =	1.60	0.57	1.15
19	6.00	4.00	4.67
20	6.00	3.50	4.00
21	4.00	3.50	6.00
22	5.00	5.50	5.67
23	11.00	5.50	6.00
24	9.00	4.50	5.00
GROUP MEAN =	6.83	4.42	5.22
GROUP VARIANCE =	6.97	0.84	0.65
QUESTION MEAN =	8.75	5.79	6.50
QUESTION VARIANCE =	34.54	4.54	5.17

DISPLAY MEAN = 7.01

DISPLAY VARIANCE = 15.95

TABLE V-c

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR NTDS DISPLAY # 1

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	7.00	6.00	7.33
2	11.00	5.00	5.33
3	11.00	5.00	5.67
4	15.00	7.00	6.67
5	12.00	5.00	7.33
6	13.00	6.50	6.33
GROUP MEAN =	11.50	5.75	6.44
GROUP VARIANCE =	7.10	0.77	0.69
7	18.00	8.00	6.00
8	5.00	7.00	4.67
9	18.00	6.50	6.67
10	9.00	5.50	7.67
11	8.00	5.00	5.00
12	12.00	8.00	15.67
GROUP MEAN =	11.67	6.67	7.61
GROUP VARIANCE =	29.07	1.57	16.78
13	8.00	8.00	11.33
14	11.00	6.50	10.00
15	12.00	4.50	5.33
16	13.00	5.50	7.33
17	7.00	10.50	4.33
18	9.00	6.00	8.33
GROUP MEAN =	10.00	6.83	7.78
GROUP VARIANCE =	5.60	4.57	7.19
19	5.00	3.50	4.00
20	14.00	3.00	4.33
21	6.00	5.00	4.33
22	7.00	4.50	9.67
23	17.00	6.00	10.67
24	9.00	5.00	8.33
GROUP MEAN =	9.67	4.50	6.89
GROUP VARIANCE =	23.07	1.20	9.11
QUESTION MEAN =	10.71	5.94	7.18
QUESTION VARIANCE =	14.91	2.66	7.65

DISPLAY MEAN = 7.94

DISPLAY VARIANCE = 12.31

TABLE V-d

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR FIGURATIVE (GREEN/RED) DISPLAY # 1

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	8.00	6.00	6.33
2	6.00	8.00	4.33
3	5.00	5.50	3.67
4	6.00	6.00	5.33
5	8.00	4.00	6.00
6	5.00	4.00	5.00
GROUP MEAN =	6.33	5.58	5.11
GROUP VARIANCE =	1.87	2.24	1.00
7	9.00	11.50	5.33
8	5.00	4.50	4.33
9	10.00	4.50	7.00
10	7.00	3.50	5.33
11	10.00	7.00	4.00
12	9.00	6.00	6.67
GROUP MEAN =	8.33	6.17	5.44
GROUP VARIANCE =	3.87	8.37	1.46
13	9.00	6.50	5.67
14	7.00	4.50	5.33
15	6.00	5.00	5.00
16	6.00	5.50	5.00
17	3.00	4.50	3.67
18	6.00	6.50	5.00
GROUP MEAN =	6.17	5.42	4.95
GROUP VARIANCE =	3.77	0.84	0.46
19	10.00	4.50	5.33
20	10.00	6.00	4.33
21	14.00	8.50	13.00
22	7.00	5.50	4.67
23	9.00	10.00	8.00
24	6.00	6.00	5.67
GROUP MEAN =	9.33	6.75	6.83
GROUP VARIANCE =	7.87	4.28	10.79
QUESTION MEAN =	7.54	5.98	5.58
QUESTION VARIANCE =	5.65	3.71	3.56

DISPLAY MEAN = 6.37

DISPLAY VARIANCE = 4.91

TABLE V-e

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

MONOCHROMATIC NTDS DISPLAY # 2

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	10.00	11.67	6.00
2	31.00	14.00	9.00
3	17.50	18.00	5.00
4	23.00	26.67	16.00
5	25.00	22.33	7.00
6	15.50	18.00	13.00
GROUP MEAN =	20.33	18.45	9.33
GROUP VARIANCE =	56.17	29.76	18.67
7	25.00	10.33	4.00
8	8.00	12.00	6.00
9	14.50	14.67	9.00
10	14.50	8.33	6.00
11	12.50	9.33	5.00
12	13.00	12.33	11.00
GROUP MEAN =	14.58	11.17	6.83
GROUP VARIANCE =	31.74	5.29	6.97
13	18.00	13.33	5.00
14	12.50	10.33	7.00
15	10.50	11.00	5.00
16	9.50	12.00	5.00
17	10.00	7.67	5.00
18	21.50	18.00	5.00
GROUP MEAN =	13.67	12.06	5.33
GROUP VARIANCE =	24.47	12.06	0.67
19	9.00	15.67	5.00
20	16.00	12.00	7.00
21	17.50	11.33	6.00
22	21.00	15.67	5.00
23	22.00	22.00	12.00
24	20.00	21.67	15.00
GROUP MEAN =	17.58	16.39	8.33
GROUP VARIANCE =	22.54	21.05	17.47
QUESTION MEAN =	16.54	14.51	7.46
QUESTION VARIANCE =	36.54	24.27	11.91
DISPLAY MEAN =	12.84		
DISPLAY VARIANCE =	38.93		

TABLE V-f

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR FIGURATIVE (BLUE/ORANGE) DISPLAY # 2

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	8.50	8.33	6.00
2	5.00	8.00	4.00
3	7.50	9.33	9.00
4	10.00	10.67	6.00
5	21.50	9.33	5.00
6	8.50	8.67	5.00
GROUP MEAN =	10.17	9.06	5.83
GROUP VARIANCE =	33.57	0.91	2.97
7	11.00	23.00	13.00
8	9.50	12.00	5.00
9	10.00	9.00	6.00
10	8.00	8.00	5.00
11	9.00	8.00	4.00
12	10.50	13.67	6.00
GROUP MEAN =	9.67	12.28	6.50
GROUP VARIANCE =	1.17	32.86	10.70
13	7.00	9.00	4.00
14	7.00	5.67	4.00
15	6.50	5.33	4.00
16	6.00	6.00	3.00
17	6.50	6.67	4.00
18	6.50	7.33	5.00
GROUP MEAN =	6.58	6.67	4.00
GROUP VARIANCE =	0.14	1.82	0.40
19	8.00	6.67	4.00
20	5.00	5.33	4.00
21	5.50	4.33	3.00
22	8.00	6.67	6.00
23	9.50	8.33	6.00
24	10.50	11.00	12.00
GROUP MEAN =	7.75	7.06	5.50
GROUP VARIANCE =	4.68	5.58	6.30
QUESTION MEAN =	8.54	8.76	5.46
QUESTION VARIANCE =	10.78	14.10	5.30

DISPLAY MEAN = 7.59

DISPLAY VARIANCE = 12.09

TABLE V-6

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR NTDS DISPLAY # 2

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	8.50	9.33	6.00
2	10.50	6.67	6.00
3	14.00	7.67	11.00
4	15.00	8.67	7.00
5	16.50	8.00	5.00
6	15.00	7.33	7.00
GROUP MEAN =	13.25	7.95	7.00
GROUP VARIANCE =	9.48	0.91	4.40
7	13.50	9.00	4.00
8	12.50	6.67	5.00
9	15.00	13.00	6.00
10	11.00	10.33	9.00
11	15.50	13.33	5.00
12	15.50	11.00	9.00
GROUP MEAN =	13.83	10.56	6.33
GROUP VARIANCE =	3.37	6.29	4.67
13	20.50	16.33	7.00
14	17.50	14.00	6.00
15	14.50	12.67	6.00
16	14.50	9.33	5.00
17	21.00	7.00	8.00
18	16.50	8.00	12.00
GROUP MEAN =	17.42	11.22	7.33
GROUP VARIANCE =	8.04	13.54	6.27
19	7.00	6.67	4.00
20	8.00	5.33	5.00
21	9.50	7.00	10.00
22	13.00	7.33	9.00
23	11.00	8.00	5.00
24	12.50	8.67	8.00
GROUP MEAN =	10.17	7.17	6.83
GROUP VARIANCE =	5.87	1.33	6.17
QUESTION MEAN =	13.67	9.22	6.88
QUESTION VARIANCE =	12.73	7.83	4.81

DISPLAY MEAN = 9.92

DISPLAY VARIANCE = 16.26

TABLE V-h

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR FIGURATIVE (GREEN/RED) DISPLAY # 2

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	12.50	10.00	5.00
2	8.50	9.67	3.00
3	10.50	6.67	4.00
4	6.00	9.00	6.00
5	15.50	9.67	5.00
6	9.00	10.33	5.00
GROUP MEAN =	12.17	9.22	4.67
GROUP VARIANCE =	12.37	1.76	1.07
7	8.00	11.33	5.00
8	5.00	6.00	5.00
9	8.00	7.33	8.00
10	8.50	6.33	4.00
11	9.00	6.67	4.00
12	12.50	10.33	7.00
GROUP MEAN =	8.50	8.00	5.50
GROUP VARIANCE =	5.80	5.10	2.70
13	9.50	12.33	5.00
14	7.50	7.33	7.00
15	12.50	9.33	5.00
16	8.50	8.00	4.00
17	11.00	10.00	5.00
18	12.00	15.33	5.00
GROUP MEAN =	9.83	10.39	5.17
GROUP VARIANCE =	2.77	8.90	0.97
19	9.50	11.67	6.00
20	14.50	7.20	7.00
21	5.50	8.67	4.00
22	6.00	8.33	5.00
23	12.00	20.67	7.00
24	12.00	9.00	7.00
GROUP MEAN =	10.25	10.89	6.00
GROUP VARIANCE =	10.48	25.29	1.60
QUESTION MEAN =	9.69	9.62	5.33
QUESTION VARIANCE =	7.34	10.23	1.62
DISPLAY MEAN =	8.22		
DISPLAY VARIANCE =	10.43		

TABLE V-1

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

MONOCHROMATIC MIES DISPLAY # 3

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	47.00	18.25	24.00
2	39.00	29.00	24.00
3	9.00	21.00	20.00
4	19.00	20.50	15.00
5	24.00	35.00	22.00
6	17.00	15.75	16.00
GROUP MEAN =	25.83	23.25	22.17
GROUP VARIANCE =	226.57	53.00	15.37
7	25.00	16.25	17.00
8	10.00	14.50	14.00
9	22.00	17.75	11.00
10	17.00	19.25	16.00
11	15.00	11.25	13.00
12	50.00	16.00	11.00
GROUP MEAN =	23.17	15.83	13.67
GROUP VARIANCE =	200.57	7.67	6.27
13	24.00	13.75	17.00
14	19.00	18.00	13.00
15	17.00	10.75	11.00
16	11.00	21.25	11.00
17	37.00	11.25	9.00
18	19.00	14.25	29.00
GROUP MEAN =	21.17	14.66	15.00
GROUP VARIANCE =	77.77	16.44	54.40
19	17.00	15.25	15.00
20	52.00	15.75	17.00
21	11.00	18.00	10.00
22	10.00	17.75	21.00
23	40.00	32.25	16.00
24	27.00	28.25	15.00
GROUP MEAN =	25.83	21.21	15.67
GROUP VARIANCE =	266.97	51.81	12.67
QUESTION MEAN =	24.00	18.79	16.12
QUESTION VARIANCE =	167.48	41.02	25.51
DISPLAY MEAN =	19.64		
DISPLAY VARIANCE =	86.65		

TABLE V-j

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR FIGURATIVE (BLUE/ORANGE) DISPLAY # 3

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	8.00	13.25	11.20
2	7.00	14.00	17.20
3	19.00	13.25	13.00
4	10.00	12.50	10.20
5	13.00	13.00	12.00
6	23.00	9.75	23.00
GROUP MEAN =	13.33	12.63	14.33
GROUP VARIANCE =	41.07	2.22	23.87
7	11.00	12.25	14.00
8	11.00	14.25	15.00
9	10.00	14.25	8.00
10	12.00	15.25	16.00
11	33.00	18.00	37.00
12	11.00	24.25	18.00
GROUP MEAN =	14.67	16.37	18.00
GROUP VARIANCE =	81.07	18.39	98.00
13	10.00	10.75	22.00
14	11.00	6.50	5.00
15	11.00	9.25	10.00
16	15.00	9.50	6.00
17	9.00	5.75	8.00
18	6.00	9.25	16.00
GROUP MEAN =	10.33	8.50	11.17
GROUP VARIANCE =	8.67	3.75	43.37
19	10.00	8.00	6.00
20	8.00	10.25	6.00
21	10.00	6.75	9.00
22	8.00	7.75	13.00
23	9.00	14.00	13.00
24	13.00	16.00	9.00
GROUP MEAN =	9.67	10.46	9.33
GROUP VARIANCE =	3.47	14.09	9.87
QUESTION MEAN =	12.00	11.99	13.21
QUESTION VARIANCE =	33.65	17.27	49.39

DISPLAY MEAN = 12.40

DISPLAY VARIANCE = 32.83

TABLE V-K

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR NTDS DISPLAY # 3

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	19.00	13.25	21.00
2	23.00	8.75	11.00
3	18.00	12.75	21.00
4	24.00	12.50	8.00
5	16.00	13.75	9.00
6	13.00	11.50	17.00
GROUP MEAN =	18.83	11.75	14.50
GROUP VARIANCE =	17.37	3.38	35.10
7	21.00	12.75	9.00
8	15.00	8.00	8.00
9	16.00	11.50	9.00
10	21.00	11.25	10.00
11	14.00	13.75	13.00
12	12.00	13.50	9.00
GROUP MEAN =	16.50	11.46	9.67
GROUP VARIANCE =	13.90	4.39	3.27
13	36.00	14.75	11.00
14	28.00	10.75	10.00
15	11.00	10.25	10.00
16	14.00	18.50	16.00
17	9.00	13.00	6.00
18	20.00	23.50	12.00
GROUP MEAN =	20.00	15.13	10.83
GROUP VARIANCE =	125.20	25.82	10.57
19	8.00	11.00	10.00
20	21.00	10.25	6.00
21	23.00	8.75	7.00
22	10.00	9.25	6.00
23	20.00	18.75	17.00
24	16.00	8.00	12.00
GROUP MEAN =	16.33	11.00	9.33
GROUP VARIANCE =	37.27	15.65	17.47
QUESTION MEAN =	17.92	12.33	11.78
QUESTION VARIANCE =	44.78	13.47	18.78
DISPLAY MEAN =	13.78		
DISPLAY VARIANCE =	33.90		

TABLE V-1

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR FIGURATIVE (GREEN/RED) DISPLAY # 3

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	11.00	9.25	15.00
2	6.00	6.00	12.00
3	16.00	8.00	7.00
4	10.00	12.00	8.00
5	13.00	8.00	10.00
6	9.00	8.00	12.00
GROUP MEAN =	10.83	8.87	10.67
GROUP VARIANCE =	11.77	2.59	8.67
7	9.00	10.25	7.00
8	6.00	7.00	7.00
9	11.00	9.00	7.00
10	6.00	9.75	8.00
11	12.00	8.75	14.00
12	9.00	13.50	10.00
GROUP MEAN =	8.83	9.71	8.83
GROUP VARIANCE =	6.17	4.69	7.77
13	11.00	8.50	10.00
14	8.00	8.25	8.00
15	10.00	10.00	6.00
16	7.00	8.50	11.00
17	9.00	6.50	6.00
18	20.00	11.25	17.00
GROUP MEAN =	10.83	8.83	9.67
GROUP VARIANCE =	22.17	2.64	17.07
19	10.00	8.50	11.00
20	9.00	9.00	9.00
21	6.00	7.25	7.00
22	9.00	9.00	7.00
23	15.00	14.75	16.00
24	11.00	14.50	20.00
GROUP MEAN =	10.00	10.50	11.67
GROUP VARIANCE =	6.80	10.63	27.87
QUESTION MEAN =	10.13	9.48	10.21
QUESTION VARIANCE =	11.36	4.96	14.52

DISPLAY MEAN = 9.94

DISPLAY VARIANCE = 12.29

TABLE V-F

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

MONOCHROMATIC MTDS DISPLAY # 4

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	11.00	25.33	9.00
2	17.00	17.33	9.50
3	11.00	25.33	14.00
4	32.00	39.00	15.00
5	32.00	35.33	15.50
6	18.00	34.33	11.00
GROUP MEAN =	20.17	29.44	12.33
GROUP VARIANCE =	92.57	66.29	8.17
7	9.00	13.33	7.00
8	8.00	11.33	8.00
9	14.00	19.00	13.00
10	11.00	15.00	8.00
11	10.00	15.00	9.50
12	13.00	18.00	11.00
GROUP MEAN =	10.83	15.28	9.42
GROUP VARIANCE =	5.37	8.16	5.04
13	13.00	30.67	9.00
14	10.00	14.67	9.50
15	12.00	25.33	11.00
16	15.00	19.67	8.00
17	10.00	15.33	11.50
18	16.00	14.00	8.00
GROUP MEAN =	12.67	19.94	9.50
GROUP VARIANCE =	6.27	45.71	2.20
19	9.00	17.00	8.00
20	22.00	17.00	13.00
21	9.00	15.33	6.00
22	11.00	19.67	10.00
23	15.00	35.00	21.00
24	24.00	23.00	25.00
GROUP MEAN =	14.67	21.17	13.83
GROUP VARIANCE =	36.67	53.15	57.37
QUESTION MEAN =	14.58	21.46	11.27
QUESTION VARIANCE =	43.82	64.85	19.54
DISPLAY MEAN =	15.77		
DISPLAY VARIANCE =	59.79		

TABLE V-n

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR FIGURATIVE (BLUE/ORANGE, DISPLAY # 4

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	12.00	10.67	7.50
2	9.00	10.00	5.00
3	8.00	7.33	7.50
4	12.00	11.00	23.00
5	13.00	10.00	7.00
6	18.00	11.33	7.50
GROUP MEAN =	12.00	10.06	9.58
GROUP VARIANCE =	12.40	2.07	44.14
7	18.00	8.00	6.00
8	16.00	12.33	10.50
9	12.00	17.00	6.00
10	37.00	16.67	17.00
11	13.00	9.00	7.00
12	31.00	21.00	10.50
GROUP MEAN =	21.50	14.00	9.50
GROUP VARIANCE =	103.50	25.76	17.80
13	24.00	12.67	5.50
14	8.00	6.67	7.50
15	7.00	9.67	6.50
16	9.00	8.33	6.50
17	7.00	8.67	4.50
18	8.00	11.33	6.50
GROUP MEAN =	10.50	9.56	6.17
GROUP VARIANCE =	44.30	4.69	1.07
19	8.00	7.33	5.50
20	14.00	7.67	6.00
21	7.00	7.00	4.50
22	9.00	7.33	8.00
23	10.00	9.67	7.50
24	13.00	9.67	7.00
GROUP MEAN =	10.17	8.11	6.42
GROUP VARIANCE =	7.77	1.50	1.74
QUESTION MEAN =	13.54	10.43	7.92
QUESTION VARIANCE =	59.04	12.36	16.84
DISPLAY MEAN =		10.63	
DISPLAY VARIANCE =		33.95	

TABLE V-o

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR NTDS DISPLAY # 4

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	15.00	8.67	7.00
2	6.00	8.67	8.00
3	17.00	8.00	6.00
4	14.00	8.33	14.00
5	13.00	9.67	7.50
6	22.00	9.67	7.50
GROUP MEAN =	14.50	8.84	8.33
GROUP VARIANCE =	27.50	0.48	8.17
7	15.00	9.33	7.00
8	8.00	7.00	6.00
9	11.00	15.67	10.00
10	14.00	8.67	7.00
11	16.00	12.00	11.00
12	21.00	20.00	10.00
GROUP MEAN =	14.17	12.11	8.50
GROUP VARIANCE =	19.77	24.12	4.30
13	23.00	13.33	8.00
14	11.70	9.33	8.00
15	11.00	10.33	11.00
16	14.00	18.33	12.50
17	18.00	9.67	6.00
18	26.00	11.00	7.50
GROUP MEAN =	17.17	12.00	8.83
GROUP VARIANCE =	39.77	11.64	5.87
19	12.00	9.33	6.00
20	12.00	8.33	8.50
21	9.00	8.00	6.00
22	10.00	14.67	9.50
23	14.00	11.67	7.00
24	15.00	11.67	7.50
GROUP MEAN =	12.00	10.61	7.42
GROUP VARIANCE =	5.20	6.48	1.94
QUESTION MEAN =	14.46	10.89	8.27
QUESTION VARIANCE =	23.56	11.12	4.70

DISPLAY MEAN = 11.21

DISPLAY VARIANCE = 19.28

TABLE V-p

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR FIGURATIVE (GREEN/RED) DISPLAY # 4

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	10.00	9.67	7.50
2	6.00	10.00	8.00
3	11.00	9.33	4.50
4	23.00	9.67	11.00
5	10.00	10.00	12.50
6	9.00	9.33	10.00
GROUP MEAN =	11.50	9.67	8.92
GROUP VARIANCE =	34.70	0.09	8.14
7	9.00	7.33	6.00
8	6.00	9.67	5.00
9	9.00	9.00	7.00
10	8.00	14.00	6.00
11	9.00	6.67	5.50
12	11.00	14.33	13.50
GROUP MEAN =	8.67	10.17	7.17
GROUP VARIANCE =	2.67	10.78	10.07
13	12.00	15.00	18.00
14	18.00	18.00	6.50
15	10.00	7.67	7.50
16	10.00	12.00	6.00
17	7.00	8.33	5.50
18	15.00	9.67	7.50
GROUP MEAN =	11.67	11.78	8.50
GROUP VARIANCE =	16.27	16.47	22.30
19	13.00	9.67	10.00
20	13.00	14.33	6.00
21	13.00	7.33	4.50
22	12.00	15.00	8.00
23	14.00	15.33	14.50
24	13.00	17.67	12.50
GROUP MEAN =	13.00	13.22	8.92
GROUP VARIANCE =	0.40	15.19	12.74
QUESTION MEAN =	11.21	11.21	8.37
QUESTION VARIANCE =	14.35	11.29	12.11
DISPLAY MEAN =	10.26		
DISPLAY VARIANCE =	14.24		

TABLE V-9

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

MONOCHROMATIC NTDS DISPLAY # 5

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	12.00	9.00	12.00
2	17.00	12.00	19.00
3	18.00	11.00	12.67
4	18.00	13.00	12.67
5	23.50	14.00	15.67
6	15.50	23.00	16.33
GROUP MEAN =	17.33	13.67	14.72
GROUP VARIANCE =	14.17	23.87	7.82
7	18.50	5.00	8.67
8	8.00	9.00	6.67
9	14.50	11.00	16.00
10	9.50	11.00	7.67
11	10.50	7.00	7.67
12	13.50	10.00	11.33
GROUP MEAN =	12.42	8.83	9.67
GROUP VARIANCE =	14.84	5.77	12.16
13	15.00	5.00	13.33
14	15.00	8.00	14.67
15	12.00	7.00	11.00
16	18.00	11.00	20.00
17	10.50	9.00	7.67
18	17.00	6.00	10.67
GROUP MEAN =	14.58	7.67	12.89
GROUP VARIANCE =	8.24	4.67	17.93
19	27.00	9.00	12.33
20	14.00	13.00	13.33
21	10.50	4.00	7.33
22	16.50	8.00	10.67
23	26.50	22.00	17.00
24	18.50	46.00	17.33
GROUP MEAN =	18.83	17.00	13.00
GROUP VARIANCE =	44.77	239.20	14.58
QUESTION MEAN =	15.79	11.79	12.57
QUESTION VARIANCE =	24.22	74.17	14.64

DISPLAY MEAN = 13.38

DISPLAY VARIANCE = 39.72

TABLE V-r

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR FIGURATIVE (BLUE/ORANGE) DISPLAY # 5

SUBJECT	TYPE	ALLEGIANCE	PCTH
1	18.20	6.00	12.33
2	14.50	4.00	7.67
3	24.50	5.00	9.67
4	14.50	5.00	9.00
5	28.00	4.00	9.33
6	11.00	4.00	10.33
GROUP MEAN =	17.08	4.67	9.72
GROUP VARIANCE =	36.94	2.67	2.41
7	32.50	6.00	7.67
8	21.00	6.00	9.67
9	22.50	6.00	8.00
10	17.50	5.00	14.67
11	15.00	8.00	12.00
12	42.00	9.00	16.33
GROUP MEAN =	25.25	6.67	11.39
GROUP VARIANCE =	121.68	2.27	12.76
13	26.00	4.00	8.33
14	9.50	3.00	8.33
15	11.50	5.00	5.67
16	8.20	8.00	6.67
17	8.50	4.00	5.33
18	9.50	4.00	7.00
GROUP MEAN =	12.17	4.67	6.89
GROUP VARIANCE =	47.37	3.07	1.63
19	15.00	4.00	8.00
20	19.00	4.00	7.00
21	7.50	4.00	7.33
22	13.50	4.00	9.33
23	14.50	5.00	11.67
24	11.50	4.00	12.67
GROUP MEAN =	13.50	4.17	9.33
GROUP VARIANCE =	14.70	2.17	5.57
QUESTION MEAN =	17.20	5.04	9.33
QUESTION VARIANCE =	75.02	2.30	7.56
DISPLAY MEAN =	10.46		
DISPLAY VARIANCE =	52.31		

TABLE V-5

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR NTDS DISPLAY # 5

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	14.50	6.00	8.00
2	12.00	4.00	11.67
3	14.50	6.00	7.67
4	24.50	5.00	8.33
5	19.00	4.00	10.67
6	33.00	5.00	9.33
GROUP MEAN =	19.58	5.00	9.28
GROUP VARIANCE =	62.74	0.80	2.56
7	22.50	6.00	8.67
8	13.00	6.00	7.67
9	20.00	5.00	7.67
10	15.00	6.00	16.00
11	13.00	4.00	10.00
12	14.50	8.00	12.67
GROUP MEAN =	16.33	5.83	10.45
GROUP VARIANCE =	15.77	1.77	10.91
13	34.00	7.00	16.67
14	15.00	5.00	10.33
15	22.50	5.00	10.00
16	17.00	10.00	17.00
17	15.00	8.00	7.67
18	17.50	6.00	9.33
GROUP MEAN =	20.17	6.83	11.83
GROUP VARIANCE =	53.47	3.77	15.86
19	8.50	5.00	7.67
20	14.00	3.00	6.00
21	8.50	3.00	8.00
22	13.50	5.00	12.00
23	13.00	8.00	9.67
24	11.50	8.00	8.67
GROUP MEAN =	11.50	5.33	8.67
GROUP VARIANCE =	6.10	5.07	4.13
QUESTION MEAN =	16.90	5.75	10.06
QUESTION VARIANCE =	42.37	2.98	8.80

DISPLAY MEAN = 10.90

DISPLAY VARIANCE = 38.90

TABLE V-t

MEAN AND VARIANCE BY GROUP, QUESTION, DISPLAY, AND TREATMENT

COLOR FIGURATIVE (GREEN/RED) DISPLAY # 5

SUBJECT	TYPE	ALLEGIANCE	BOTH
1	11.50	5.00	9.67
2	8.50	3.00	9.00
3	10.50	4.00	7.00
4	12.50	5.00	11.67
5	11.50	4.00	9.00
6	10.50	4.00	10.33
GROUP MEAN =	11.83	4.17	9.45
GROUP VARIANCE =	7.07	0.57	2.43
7	17.00	5.00	10.67
8	22.50	4.00	8.67
9	14.50	7.00	7.00
10	8.50	4.00	6.33
11	14.00	3.00	6.67
12	13.00	5.00	11.00
GROUP MEAN =	14.92	4.67	8.39
GROUP VARIANCE =	21.54	1.87	4.24
13	11.50	5.00	8.00
14	13.00	4.00	5.67
15	10.00	4.00	7.33
16	11.50	5.00	11.67
17	12.50	4.00	6.33
18	10.00	5.00	8.67
GROUP MEAN =	11.42	5.00	7.95
GROUP VARIANCE =	1.54	2.40	4.51
19	17.50	5.00	11.00
20	16.50	5.00	14.00
21	13.50	3.00	6.33
22	16.50	4.00	7.67
23	19.50	5.00	15.67
24	19.00	10.00	14.33
GROUP MEAN =	17.08	5.33	12.17
GROUP VARIANCE =	4.64	5.87	24.00
QUESTION MEAN =	13.81	4.79	9.49
QUESTION VARIANCE =	16.19	2.52	10.46
DISPLAY MEAN =		9.36	
DISPLAY VARIANCE =		22.24	

TABLE VI-8

MEAN AND VARIANCE BY QUESTION, DISPLAY, AND TREATMENT

DISPLAY # 1

TREATMENT		TYPE	ALLEGIANCE	BOTH
		MONOCHROMATIC NIDS		
MEAN	=	13.12	9.38	7.92
VARIANCE	=	42.11	15.29	6.99
		COLOR FIGURATIVE (BLUE/ORANGE)		
MEAN	=	8.75	5.79	6.50
VARIANCE	=	34.54	4.54	5.17
		COLOR NIDS		
MEAN	=	10.71	5.94	7.18
VARIANCE	=	14.91	2.66	7.65
		COLOR FIGURATIVE (GREEN/RED)		
MEAN	=	7.54	5.98	5.58
VARIANCE	=	5.65	3.71	3.56

TABLE VI-c

MEAN AND VARIANCE BY QUESTION, DISPLAY, AND TREATMENT

DISPLAY # 2

TREATMENT		TYPE	ALLEGIANCE	BOTH
MONOCHROMATIC NIDS				
MEAN	=	16.54	14.51	7.46
VARIANCE	=	36.54	24.27	11.91
COLOR FIGURATIVE (BLUE/ORANGE)				
MEAN	=	8.54	8.76	5.46
VARIANCE	=	12.78	14.10	5.30
COLOR NIDS				
MEAN	=	13.67	9.22	6.88
VARIANCE	=	12.73	7.83	4.81
COLOR FIGURATIVE (GREEN/RED)				
MEAN	=	9.69	9.62	5.33
VARIANCE	=	7.34	10.23	1.62

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TABLE VI-c

MEAN AND VARIANCE BY QUESTION, DISPLAY, AND TREATMENT

DISPLAY # 3

TREATMENT		TYPE	ALLEGIANCE	BOTH
MONOCHROMATIC NTDS				
MEAN	=	24.20	18.79	16.12
VARIANCE	=	167.48	41.22	25.51
COLOR FIGURATIVE (BLUE/ORANGE)				
MEAN	=	12.20	11.99	13.21
VARIANCE	=	33.65	17.27	49.39
COLOR NTDS				
MEAN	=	17.92	12.33	11.08
VARIANCE	=	44.78	13.47	18.76
COLOR FIGURATIVE (GREEN/RED)				
MEAN	=	10.13	9.48	10.21
VARIANCE	=	11.33	4.96	14.52

TABLE VI-a

MEAN AND VARIANCE BY QUESTION, DISPLAY, AND TREATMENT

DISPLAY # 4

TREATMENT		TYPE	ALLEGIANCE	BOTH
MONOCHROMATIC NTDS				
MEAN	=	14.58	21.46	11.27
VARIANCE	=	43.82	64.85	19.54
COLOR FIGURATIVE (BLUE/ORANGE)				
MEAN	=	13.54	10.43	7.92
VARIANCE	=	59.04	12.36	16.84
COLOR NTDS				
MEAN	=	14.46	10.89	8.27
VARIANCE	=	23.56	11.12	4.70
COLOR FIGURATIVE (GREEN/RED)				
MEAN	=	11.21	11.21	8.37
VARIANCE	=	14.35	11.29	12.11

TABLE VI-e

MEAN AND VARIANCE BY QUESTION, DISPLAY, AND TREATMENT

DISPLAY # 5

TREATMENT		TYPE	ALLEGIANCE	BOTH
		MONOCHROMATIC NTDS		
MEAN	=	15.79	11.79	12.57
VARIANCE	=	24.22	74.17	14.86
		COLOR FIGURATIVE (BLUE/ORANGE)		
MEAN	=	17.02	5.04	9.33
VARIANCE	=	75.02	2.30	7.56
		COLOR NTDS		
MEAN	=	16.90	5.75	10.06
VARIANCE	=	42.37	2.98	8.80
		COLOR FIGURATIVE (GREEN/RED)		
MEAN	=	13.81	4.79	9.49
VARIANCE	=	13.19	2.52	10.46

TABLE VII

MEAN AND VARIANCE BY QUESTION AND TREATMENT

TREATMENT		TYPE	ALLEGIANCE	BOTH
		MONOCHROMATIC NTDS		
MEAN	=	16.61	15.19	11.07
VARIANCE	=	75.11	62.18	25.48
		COLOR FIGURATIVE (BLUE/ORANGE)		
MEAN	=	11.97	8.40	8.46
VARIANCE	=	51.24	16.86	23.64
		COLOR NTDS		
MEAN	=	14.73	8.83	8.69
VARIANCE	=	33.24	14.32	11.34
		COLOR FIGURATIVE (GREEN/RED)		
MEAN	=	10.48	8.22	7.80
VARIANCE	=	14.26	12.22	12.20

TABLE VIII

MEAN AND VARIANCE BY TREATMENT

TREATMENT	MEAN	VARIANCE
MONOCHROMATIC NTDS	14.35	59.61
COLOR FIGURATIVE (BLUE/ORANGE)	9.62	33.18
COLOR NTDS	12.75	27.46
COLOR FIGURATIVE (GREEN/RED)	8.83	14.21

APPENDIX G

EXPERIMENT 2 SCORES

MONOCHROMATIC NTDS			COLOR FIGURATIVE (GREEN/RED)		
TYPE	ALLEGIANCE	TOTAL	TYPE	ALLEGIANCE	TOTAL
14	15	29	16	16	32
15	15	30	14	13	27
16	15	31	15	12	27
7	6	13	16	12	28
14	12	26	10	12	22
12	11	23	13	15	28
14	14	28	13	12	25
14	16	30	18	16	34
17	18	35	16	12	28
13	10	23	14	14	28
13	11	24	12	10	22
18	18	36	13	13	26
MEAN=13.92	13.42	27.33	14.17	13.08	27.25
VARIANCE= 7.72	12.45	38.24	4.70	3.36	12.02

APPENDIX B

COMPUTER PROGRAM TO CALCULATE MEANS AND VARIANCES

```
c       This program calculates means and variances
c       for n-1 degrees of freedom.
        real array(4,5,24,3),csum(4,5,4,3),cxbar(4,5,4,3)
        real cvar(4,5,4,3),qsum(4,5,3),qxbar(4,5,3)
        real qvar(4,5,3),dxbar(4,5),dvar(4,5)
        real txbar(4,3),tvar(4,3)
        real mxbar(4),mvar(4)
        real sum,csquare,first,second
        integer mode,disp,subj,ques,group
c       Input data from file called matrix.
                do 10 mode=1,4
                do 11 disp=1,5
                do 12 subj=1,24
                read(5,1)(array(mode,disp,subj,ques), ques=1,3)
   12           continue
   11           continue
   10           continue
c       Calculate the group means and variances.
        do 41 mode=1,4
        do 42 disp=1,5
        do 43 ques=1,3
        sum=0.0
        do 44 subj=1,24
        sum = sum + array(mode,disp,subj,ques)
        if(subj .eq. 6)csum(mode,disp,1,ques)=sum
        if(subj .eq. 6)cxbar(mode,disp,1,ques)=sum/6.0
        if(subj .eq. 6)sum=0.0
        if(subj .eq. 12)csum(mode,disp,2,ques)=sum
        if(subj .eq. 12)cxbar(mode,disp,2,ques)=sum/6.0
        if(subj .eq. 12)sum=0.0
        if(subj .eq. 18)csum(mode,disp,3,ques)=sum
        if(subj .eq. 18)cxbar(mode,disp,3,ques)=sum/6.0
        if(subj .eq. 18)sum=0.0
        if(subj .eq. 24)csum(mode,disp,4,ques)=sum
        if(subj .eq. 24)cxbar(mode,disp,4,ques)=sum/6.0
   44   continue
   43   continue
   42   continue
   41   continue
        do 45 mode=1,4
        do 46 disp=1,5
        do 47 ques=1,3
        csquare=0.0
        do 48 subj=1,6
        first=array(mode,disp,subj,ques)
```

```
      second=cxbar(mode,disp,1,ques)
      csquare=csquare + (first - second)**2.0
   48 continue
      cvar(mode,disp,1,ques)=csquare/5.0
      csquare=0.0
      do 49 subj=7,12
      first=array(mode,disp,subj,ques)
      second=cxbar(mode,disp,2,ques)
      csquare=csquare + (first - second)**2.0
   49 continue
      cvar(mode,disp,2,ques)=csquare/5.0
      csquare=0.0
      do 50 subj=13,18
      first=array(mode,disp,subj,ques)
      second=cxbar(mode,disp,3,ques)
      csquare=csquare + (first - second)**2.0
   50 continue
      cvar(mode,disp,3,ques)=csquare/5.0
      csquare=0.0
      do 51 subj=19,24
      first=array(mode,disp,subj,ques)
      second=cxbar(mode,disp,4,ques)
      csquare=csquare + (first - second)**2.0
   51 continue
      cvar(mode,disp,4,ques)=csquare/5.0
   47 continue
   46 continue
   45 continue
C     Calculate the question means and variances.
      do 52 mode=1,4
      do 53 disp=1,5
      do 54 ques=1,3
      sum=0.0
      do 55 group=1,4
      sum = sum + csum(mode,disp,group,ques)
   55 continue
      qsum(mode,disp,ques)=sum
      qxbar(mode,disp,ques)=sum/24.0
      csquare=0.0
      do 56 subj=1,24
      first=array(mode,disp,subj,ques)
      second=qxbar(mode,disp,ques)
      csquare=csquare + (first - second)**2.0
   56 continue
      qvar(mode,disp,ques)=csquare/23.0
   54 continue
   53 continue
   52 continue
C     Calculate the display means and variances.
      do 57 mode=1,4
      do 58 disp=1,5
      sum = 0.0
```

```
      do 59 ques=1,3
      sum=sum + qsum(mode,disp,ques)
   59 continue
      dxbar(mode,disp)=sum/72.0
      csquare=0.0
      do 60 subj=1,24
      do 61 ques=1,3
      first=array(mode,disp,subj,ques)
      second=dxbar(mode,disp)
      csquare=csquare + (first - second)**2.0
   61 continue
   60 continue
      dvar(mode,disp)=csquare/71.0
   58 continue
   57 continue
C     Calculate the treatment mean & variance.
      do 65 mode=1,4
      sum = 0.0
      do 66 disp=1,5
      do 67 subj=1,24
      do 68 ques=1,3
      sum=sum + array(mode,disp,subj,ques)
   68 continue
   67 continue
   66 continue
      mxbar(mode)=sum/360.0
      csquare=0.0
      do 69 disp=1,5
      do 70 subj=1,24
      do 71 ques=1,3
      first=array(mode,disp,subj,ques)
      second=mxbar(mode)
      csquare=csquare + (first - second)**2.0
   71 continue
   70 continue
   69 continue
      mvar(mode)=csquare/359.0
   65 continue
C     Calculate the treatment/question mean & variance.
      do 72 mode=1,4
      do 73 ques=1,3
      sum = 0.0
      csquare = 0.0
      do 74 disp=1,5
      sum = sum + qsum(mode,disp,ques)
   74 continue
      txbar(mode,ques) = sum/120.0
      do 75 disp=1,5
      do 76 subj=1,24
      first=array(mode,disp,subj,ques)
      second=txbar(mode,ques)
      csquare=csquare + (first - second)**2.0
```

```
 76     ccntinue
 75     continue
        tvar(mode,ques)=csquare/119.0
 73     continue
 72     continue
c       Output the data.
          do 63 disp=1,5
          do 62 mode=1,4
          write(6,105)
          write(6,125)
          write(6,150)
          if(mode .eq. 1)write(6,2)disp
          if(mode .eq. 2)write(6,3)disp
          if(mode .eq. 3)write(6,4)disp
          if(mode .eq. 4)write(6,5)disp
          write(6,7)
          do 64 subj=1,24
          write(6,8)subj,(array(mode,disp,subj,ques), ques=1,3)
          if(subj .eq. 24)go to 100
          if(subj .eq. 18)go to 112
          if(subj .eq. 12)go to 120
          if(subj .eq. 6)go to 130
        go to 64
 130    write(6,20)(cxbar(mode,disp,1,ques), ques=1,3)
        write(6,21)(cvar(mode,disp,1,ques), ques=1,3)
        go to 64
 120    write(6,20)(cxbar(mode,disp,2,ques), ques=1,3)
        write(6,21)(cvar(mode,disp,2,ques), ques=1,3)
        go to 64
 110    write(6,20)(cxbar(mode,disp,3,ques), ques=1,3)
        write(6,21)(cvar(mode,disp,3,ques), ques=1,3)
        go to 64
 100    write(6,20)(cxbar(mode,disp,4,ques), ques=1,3)
        write(6,21)(cvar(mode,disp,4,ques), ques=1,3)
 64     continue
        write(6,22)(qxbar(mode,disp,ques), ques=1,3)
        write(6,23)(qvar(mode,disp,ques), ques=1,3)
        write(6,24)axbar(mode,disp)
        write(6,25)avar(mode,disp)
 62     continue
 63     continue
        do 77 disp=1,5
        write(6,105)
        write(6,126)
        write(6,32)
        write(6,33)disp
        write(6,34)
        do 78 mode=1,4
              if(mode .eq. 1)write(6,35)
              if(mode .eq. 2)write(6,36)
              if(mode .eq. 3)write(6,37)
              if(mode .eq. 4)write(6,38)
```

```
      write(6,39)(qxbar(mode,disp,ques), ques=1,3)
      write(6,40)(qvar(mode,disp,ques), ques=1,3)
78    continue
77    continue
      write(6,105)
      write(6,127)
      write(6,500)
      write(6,34)
      do 99 mode=1,4
            if(mode .eq. 1)write(6,35)
            if(mode .eq. 2)write(6,36)
            if(mode .eq. 3)write(6,37)
            if(mode .eq. 4)write(6,38)
      write(6,39)(txbar(mode,ques), ques=1,3)
      write(6,40)(tvar(mode,ques), ques=1,3)
99    continue
      write(6,105)
      write(6,128)
      write(6,26)
      write(6,27)
        do 97 mode=1,4
        if(mode .eq. 1)write(6,28)mxbar(mode),mvar(mode)
        if(mode .eq. 2)write(6,29)mxbar(mode),mvar(mode)
        if(mode .eq. 3)write(6,30)mxbar(mode),mvar(mode)
        if(mode .eq. 4)write(6,31)mxbar(mode),mvar(mode)
97      continue
      stop
1   format(3(f8.2))
105 format('1',//,1x,'APPENDIX F',/)
125 format(1x,'TABLE V',/)
126 format(1x,'TABLE VI',/)
127 format(1x,'TABLE VII',/)
128 format(1x,'TABLE VIII',//)
150 format(1x,'MEAN AND VARIANCE BY GROUP, QUESTION,
    DISPLAY, AND TREA
   *TMENT',/)
2   format(1x,'MONOCHROMATIC NTDS DISPLAY # ',i2)
3   format(1x,'COLOR FIGURATIVE (BLUE/ORANGE) DISPLAY#',i2)
4   format(1x,'COLOR NTDS DISPLAY # ',i2)
5   format(1x,'COLOR FIGURATIVE (GREEN/RED) DISPLAY #',i2)
7   format(1x,'SUBJECT',t24,'TYPE',t38,'ALLEGIANCE',t56,
    'BOTH',/)
8   format(4x,i2,t22,f7.2,t38,f7.2,t54,f7.2)
20  format(/,1x,'GROUP MEAN  =',t22,f7.2,t38,f7.2,t54,f7.2)
21  format(1x,'GROUP VARIANCE=',t22,f7.2t38,f7.2t54,f7.2,/)
22  format(1x,'QUESTION MEAN =',t22,f7.2t38,f7.2t54,f7.2)
23  format(1x,'QUESTION VAR =',t22,f7.2,t38,f7.2,t54,f7.2)
24  format(1x,'DISPLAY MEAN =',t22,f7.2)
25  format(1x,'DISPLAY VARIANCE  =',t22,f7.2)
26  format(///,1x,'MEAN AND VARIANCE BY TREATMENT',//)
27  format(/,1x,'TREATMENT',t40,'MEAN',t50,'VARIANCE',/)
28  format(//,1x,'MONOCHROMATIC NTDS',t38,f7.2,t50,f7.2)
```

```
29  format(//,1x,'COLOR FIG (BLUE/ORANGE)'t38f7.2t50f7.2)
30  format(//,1x,'COLOR NTDS't38,f7.2,t50,f7.2)
31  format(//,1x,'COLOR FIG (GREEN/RED)'t38,f7.2,t50,f7.2)
32  format(//,1x,'MEAN AND VARIANCE BY QUESTION,
    DISPLAY, AND TREA
   *TMENT',//)
33  format(/,1x,'DISPLAY #',i2)
34  format(//,1x,'TREATMENT't33'TYPE't43'ALLEGIANCE't56'BOTH')
35  format(//,1x,'MONOCHROMATIC NTDS')
36  format(//,1x,'COLOR FIGURATIVE (BLUE/ORANGE)')
37  format(//,1x,'COLOR NTDS')
38  format(//,1x,'COLOR FIGURATIVE (GREEN/RED)')
39  format(/,1x,'MEAN          =',t31,f7.2,t43,f7.2,t54,f7.2)
40  format(1x,'VARIANCE      =',t31,f7.2,t43,f7.2,t54,f7.2,/)
500 format(///,1x,'MEAN AND VARIANCE BY
    QUESTION AND TREATMENT',//)
    end
```

LIST OF REFERENCES

1. Ciccone, D.S., et. al., A Framework for the Development of Improved Tactical Symbology, U.S. Army Research Institute for the Behavioral and Social Sciences, 1979.

2. Hemingway, P.W., et. al., Study of Symbology for Automated Graphic Displays, U.S. Army Research Institute for the Behavioral and Social Sciences, 1979.

3. Steinkraus, L.W., Brig Gen, USAF, "Command and Control", Ordnance, March-April, 1971, pp. 440-443.

4. Edge, R.L., Maj Gen, USAF, "Command and Control Systems What are They? Who Needs Them?", Signal, March 1975, pp. 23-26.

5. Steinkraus, L.W., Brig Gen, USAF, "Command and Control", Ordnance, March-April, 1971, pp. 440-443.

6. Paschall, L.M., Maj Gen, USAF, "The Command and Control Revolution", Air Force Magazine, July, 1973, pp. 38-41.

7. Smith, D.L. (Editor), Graphic Displays, A Human Engineering Guide for Using Color in CRT Command and Control Displays, Lockheed Missiles and Space Co., Inc., Space Systems Division Sunnyvale, CA, 1978.

8. Richards, F.R., A User's Guide to the OA3660 APL Workspace, Naval Postgraduate School, October 1978, pp. 1-80.

9. McCarty, F.G.,"Computer Graphics for Command and Control", Signal, February 1982, pp. 61-63.

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